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RENEWABLE AND OTHER ALTERNATIVE ENERGY SOURCES

HEARING

BEFORE THE

SUBCOMMITTEES ON
ENERGY RESEARCH AND DEVELOPMENT

AND

MINERAL RESOURCES DEVELOPMENT AND PRODUCTION

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

ON THE

STATUS OF RENEWABLE AND OTHER ALTERNATIVE ENERGY SOURCES

ALBUQUERQUE, NM, NOVEMBER 1, 1990

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RENEWABLE AND OTHER ALTERNATIVE ENERGY SOURCES

THURSDAY, NOVEMBER 1, 1990

U.S. SENATE, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT, AND THE SUBCOMMITTEE ON MINERAL RESOURCES DEVELOPMENT AND PRODUCTION, OF THE COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Albuquerque, NM.

The subcommittees met, pursuant to notice, at 9:40 a.m., at BDM Corp., 2301 Buena Vista, Albuquerque, NM, Hon. Jeff Bingaman, presiding.

OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

Senator BINGAMAN. This is a joint hearing of the two subcommittees of the Senate Energy Committee. One is the Subcommittee on Mineral Resources Development and Production that I Chair, and the other is Subcommittee on Energy Research and Development that Mr. Ford from Kentucky Chairs.

We have today called a hearing to discuss alternative energy sources and renewable energy sources. I think there is growing interest in this issue. Again, this is an issue that comes and goes on our national agenda unfortunately. In the Energy and Water Development Appropriations bill, which was sent to the President last week, the research and development funding for solar, geothermal energy was increased by about $25 million over the administration's request. Funding for nuclear research and development was reduced by about $60 million.

The increase in solar and geothermal funding comes on top of an administration request for these programs, and it was substantially more generous than we had been receiving in recent years.

During the 1980's I think it is fair to say that the Reagan administration consistently requested starvation budgets for renewable energy research and development. Unfortunately we had something of an atmosphere of confrontation over some of those issues, and I fear little progress was achieved in developing a coherent Federal research program for renewable energy.

We have seen a modest promise of cooperation in the administration's 1991 budget requests, and I hope this will be followed through with significant attention to these issues in the coming months and coming years.

In the past we have done the research in many cases but failed to take the steps necessary to insure that the technology actually was applied commercially. As a result renewable energy technology has been developed in the United States, but unfortunately has been commercialized in many cases by foreign firms. For example, Atlantic Richfield's promising photovoltaic business was bought by the German firm Seimens. We are all aware, of course, the Japanese have shown great interest in developing workable products making use of renewable energy sources.

The National Energy Strategy this administration presents this next year has been prepared to include a thorough revitalization of our efforts to bring renewable energy technologies to the marketplace.

We need to do more good research and development in renewable energy. We also need to assist private sector firms in carrying out the product development work that must take place once a proven concept has been achieved. If we want these technologies to enter the marketplace, we need to follow through on the research and investment in commercialization.

Obviously, if we succeed in these efforts, we will have rewards in several respects. Renewable energy technologies can contribute to maintaining some degree of energy independence for the country. In addition, renewable energy technologies are environmentally benign. Of course, that is a major issue for all of us.

We are fortunate to have an outstanding group of witnesses today. Before we hear from the first witness, let me just cover a few administrative details. We would like the witnesses to summarize their testimony and take maybe 10 minutes or so to do that, so that there is time for questions. After the hearing we will keep the record open for 2 weeks. If anybody wishes to submit written testimony to be included in that record, we will be glad to receive that. We urge you to do so. You can mail it to my office here in Albuquerque, or in Washington, or to the Senate Energy Committee.

I am very pleased that my colleague on the energy committee, Senator Domenici, is able to join us today. He has been very active in this set of issues for a long time.

Pete, why don't you go ahead with any statements you want to make.

STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Senator **Domenici**. Thank you very much, Mr. Chairman, and hello everyone. It is nice to be with you.

I am not sure how long I can stay. I probably will be here an hour, and I hope you will understand. It is sort of that time of year. I do have an election.

Senator **Bingaman**. You mean the day after Halloween?

Senator **Domenici**. Yes. I did not go out on the streets. I went up there where it was safe. There were thousands of little children up there at the two big shopping centers.

Senator Bingaman, I think it is good that we hold this hearing.

But it does seem to me that our country really is foolish. When you play baseball, you have three strikes and you are out. We have two strikes on energy policy. Those two giant strikes that occurred in the past decade when we found out that we were in terrible shape because of our dependence on oil for everyday living for the American economy. Now, we have another strike, and it is on the way from the pitcher's mound there to home plate where we are standing, and I just hope this time we do not strike out because I do not know how many times they are going to give us to hit that ball.

The time has come to do something in a dramatic way of getting to America without totally weakening our economic future, and in a sense keeping alive our opportunities and growth, finding ways to minimize our dependence on oil. There are no easy answers. They are complicated and difficult, and those who have easy answers are most probably wrong.

But this Middle East situation makes it very timely. It is timely because Congress has just passed some legislation which will have a very far-reaching impact on the development of renewable energy, probably more so than anything we have done in the past 10 or 15 years. Some of you might be thinking, especially those who are close to what is going on there that I will toot my own horn and say it was the extension of PURPA, but I am not going to do that. That is pretty far reaching and is going to do some dramatic things for wind, geothermal and solar. But I think actually that it is ironic, but I think the Clean Air Act is probably the most significant piece of legislation that is going to have an affect on alternative fuels.

Let me tell you why. I think we all now know that it is unique in that it will cut sulfur dioxide in half. That is unique for any country to say we are going to do that. But the part that is going to force alternatives is that at the same time this country put a cap on SO_2, and that is a literal cap. When you get to the half, you cannot produce any more.

Well, you know the United States is known for its ingenuity. American business when pushed is ingenuous. Frankly, I believe because America is going to have to produce more electrical energy that that cap is going to push down on American industry, and they are going to have to find alternative ways to generate the electricity that that cap imposes on them.

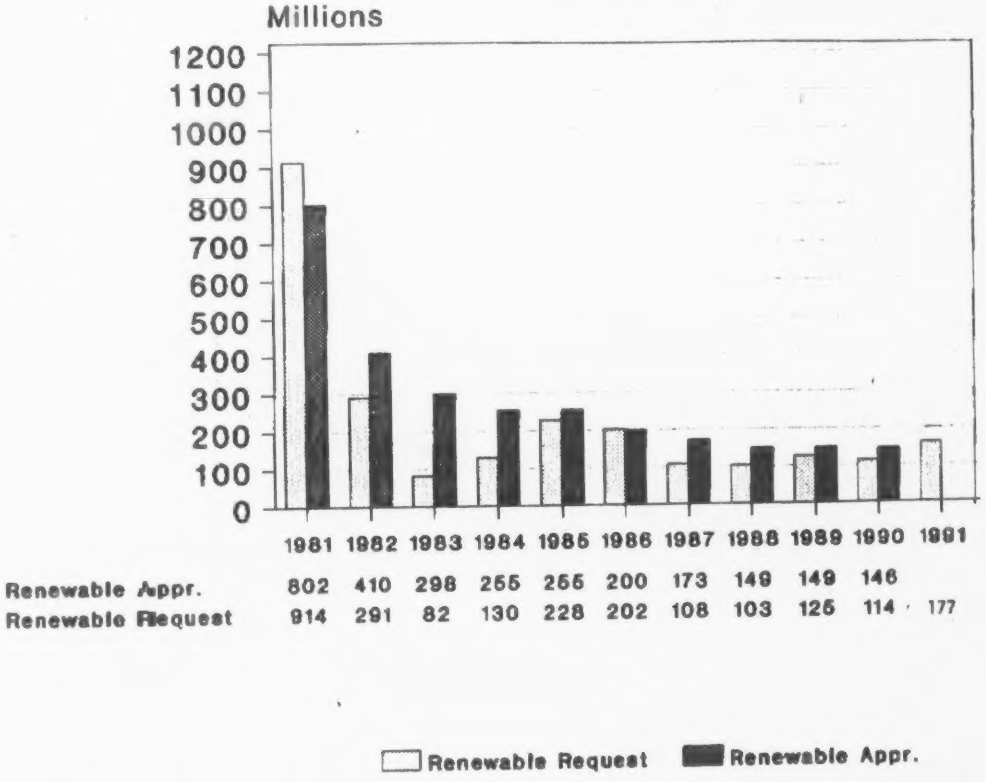
Two things are going to happen. One is obvious. We are going to clean the stacks tremendously. That means that kind of technology is going to go wild, and we will do some very exciting things. I believe the utility companies are going to invest in and push alternative energy sources to fill that gap, because the needs are going to exceed those that can be produced normally and easily by that gap. And some of that will be natural gas, I acknowledge.

Having said that, let me just suggest that solar, geothermal, and wind energy have come an enormously long way in the past decade. There is much criticism, and perhaps some of it is justifiable, of research budgets. Although I do not happen to agree with my good friends, and I would just ask that my version of the conservation and renewable budgets for the last 10 years may be made a part of the record, and we have no argument. Just put them in.

Senator BINGAMAN. We will put it in the record.

[The information referred to follows:]

Conservation and Renewable R&D
Budget History



	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Renewable Appr.	802	410	298	255	255	200	173	149	149	146	
Renewable Request	914	291	82	130	228	202	108	103	125	114	177

Senator **Domenici**. Thank you. Frankly, what moved solar energy, geothermal, and wind energy, Mr. Chairman, was this funny act called PURPA, Public Utilities Regulatory Policy Act, and what it has done is force utilities across this country the first 8 or 9 years to accept these sources of energy, even if they were high, even if they were too expensive. They had to buy them and put them on the grid. Now, it is moving in the direction where they are very close to market. They need 3 or 4 more years and that is what we got them, and they need to produce solar in larger sizes and wind and geothermal in larger sizes. I think the decade will find all three of those absolutely at market for the utilities industry. I think that is very exciting.

Thank you very much, Mr. Chairman.

Senator **Bingaman**. Thank you very much.

Our first witness today is Hon. Michael Davis, who is the Assistant Secretary for Conservation and Renewable Energy at the Department of Energy. He has had a very long and active career in solar energy issues, energy efficiency issues, and we look forward to hearing as to what the present status of our efforts are.

Please go right ahead. Thank you for coming.

STATEMENT OF J. MICHAEL DAVIS, ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY

Mr. **Davis**. Thank you, Mr. Chairman. Good morning everybody.

I would just submit my testimony for the record and offer a few general comments. I think there may be more value to discussing some of these topics.

I would certainly agree with Senator Domenici. Recent legislation, both the PURPA extension, and in particular the Clean Air Act, will have a major effect, certainly on renewable energy generated electricity. In addition to the caps on SO_2, there are also some trade in emissions. There are some allowances, SO_2 set asides, if you will. Those will become fundamentally important.

I left Washington on Sunday, and I have spent 3 days with very progressive electric utilities around the country. Some of those utilities are really beginning to understand the benefits renewable technologies offer to them in terms of how quickly you can build them; you can build them in small increments, which is an obvious environmental benefit. The cost and performance of those technologies have improved substantially. I will touch on some of those technologies and the progress that has been made.

Pacific Gas and Electric, one of the largest investor-owned utilities in the country, uses renewable technologies for 45 percent of its generating capacity. If you will look around you will see progressive utilities beginning to realize these benefits. They also are investing on the demand side of the equation, trying to produce renewable energy that is cost effective. They see renewables now as legitimate opportunities.

In our activities to develop the National Energy Strategy that President Bush so rightly called for in July of 1989, it has been clear all across the country that people believe that our investments in renewable technology are justified and need to be sustained—they need to be handled very carefully. I have been part of that industry for a long time. I do not want to see investments get back out of control, but I do want to see investments made carefully, made with the full view of the competition, and that means all energy technology, and made in sustained ways so that the private sector knows what to count on.

How do you know how to invest if the rules of the road are going to change a year down the road? That makes it difficult for anybody to acquire resources. These sorts of uncertainties impact renewables just like any other energy technology. So a lot is happening. We have made progress—those budgets came down. There was a reason for that happening. That reduction has caused us to focus. It has caused some research and development to be very focused. As a result we have seen some cost and performance improvement. We have seen major improvements in solar thermal technology, from 30 cents a kilowatt hour down to 12. We have seen wind move from 50 cents down to 8 to 10 cents a kilowatt hour. We have seen photovoltaics come basically from off the scale down to 30 cents a kilowatt hour. We have seen renewable alcohol, the opportunity to produce ethanol from other than corn, begin to come into play. There is a huge opportunity for renewables in the transportation sector in terms of liquid fuel.

These are not just "what ifs" any more. We have the science in hand. In many cases we have the technology in hand and we can begin to reduce it to practice so that we can acquire those resources. In other cases, we have the technology in the laboratory, and we have to move that to practice. What I call "reduced to practice."

I think this delegation here has been so important in helping for a long time to make this happen. Here is one of the keys. We need a better relationship than we have ever had before between the Government and private sector. I am kind of a down-home guy. I would say; let us get in cahoots. Let us do the best job we can rebuilding America's energy infrastructure, but do it in a careful, measured way with cooperation from Government and industry.

Senator BINGAMAN. Can I ask you just to pull that microphone on your left a little closer. I think that is the one that perhaps that is going into the loudspeaker system. Thank you.

Mr. DAVIS. Thank you. I really think that is about it, Mr. Chairman. I think the progress is well documented. That progress has come at a point in time when budgets ramped down. I believe the benefit has been to focus people to realize we do not have enough money to do everything. We have to focus and choose our investments well.

I would say this about the renewable technologies, and it is a fear I have. In many respects, all of the different renewables and energy-efficiency technologies are kind of a mini-set of the overall energy situation in this country. We have a whole bunch of very special interests. If you look at the large energy equation, it is also a group of very powerful interests. As long as everybody in the past has gotten what they wanted, we basically called that balance, and we basically called that energy policy. We no longer have enough money to approach it that way. We have to put all the technological opportunities into a better framework of competition so we can make better investments.

The same is true within the renewable budget itself. I think it is a mistake to try to be all things to all people. There are certain areas of that budget that need to grow, so that we just do not continue to do research forever. There is a level below which you never make any progress, but over time you end up spending a lot of money.

So we have to do the same thing with renewable technology. We have to challenge ourselves. Put some business in the system. Create an analytic base that will make good investment choices. That is what we need to bring to your consideration.

I think last year we made a lot of progress doing that. At one of our national strategy hearings Senator Domenici hit on a real important topic. He said, "We need science to grow but we need growth to pay for the science." And science just for science sake, research for just research sake is not well directed. If it does not have a clear purpose in the end, it is going to cost us more money than we can afford. What I am trying to do with renewable technologies is continue that focus.

Now, I think we have also made a case—and it is always challenging to make these cases, at least to R&D—to expand those budgets. You all have responded and we certainly appreciate that. You have also responded in terms of important legislation. I am very optimistic about what we can do in the next 10 years with renewable technology in this country.

I appreciate your opportunity today to address these issues.

[The prepared statement of Mr. Davis follows:]

PREPARED STATEMENT OF J. MICHAEL DAVIS, ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY

Mr. Chairman, I am pleased to have the opportunity to testify at this field hearing on the status of renewable energy technologies and the progress made by DOE in developing programs which will lead to the further use of our vast and indigenous renewable energy resources.

Renewable energy is a practical reality today, satisfying nearly 10% of our nation's energy requirements—chiefly through hydropower and combustion of wood and waste. That contribution will grow in the years ahead—a consensus that emerged clearly during the development of the National Energy Strategy (NES) As the Interim Report on the NES noted in April:

> Witnesses exhibited broad general support for renewable energy, often citing the following reasons:
>
> > Renewable energy has large potential and is capable of adding significantly and reliably to energy supply.
> >
> > Renewable energy can help reduce certain risks and vulnerabilities associated by the public with the Nation's increasing reliance on imported oil.
> >
> > The production and consumption of energy from renewable sources, with some exceptions, are activities generally believed to be less harmful to the environment than the production and consumption of energy from other sources.

Renewable energy technologies have experienced substantial progress in reducing costs and improving conversion efficiencies, and there are many success stories. Solar thermal electric technology, using parabolic trough collectors, provides an excellent example. Sandia Labs and their contractors pioneered the modern development of this technology, which was adopted by LUZ International. Through continued development and commercial experience, LUZ brought the cost of electricity from this technology down from 24 cents per kilowatt-hour (kWh). Today, at a cost of 8 to 12 cents per kWh, LUZ is able to compete for a variety of utility applications.

Improved turbine design, in combination with excellent wind sites, has enabled wind energy producers to make important supply contributions to the California electric grid. Today there is approximately 1,400 MW of installed wind turbine capacity on line, primarily in California and Hawaii and top-rated systems have produced energy at costs as low as 8 cents per kWh.

Solar building applications have also grown in recent years. Both solar water heating systems and passive solar heating systems for residential end uses have widespread application. Approximately one million active systems and 250,000 passive systems (many of them here in New Mexico and throughout the Southwest) have been installed.

Fundamentally, there are three primary issues which will determine the success of renewable technologies: technology development, industrial development, and marketplace acceptance. These in turn are dependent on a variety of factors, ranging from budgetary constraints to foreign competition to consumer preference. It is imperative that industry, the Federal Government, and the States collaborate more effectively with each other to more effectively leverage limited public and private resources.

We now have available a portfolio of renewable technologies that are capable of making significant contributions to U.S. energy supplies; however, some technological advances are still required to enable developers to expand upon a proven base of applications. Furthermore, a variety of economic, statutory, regulatory, and technological constraints have inhibited some renewable energy resources from being developed or fully utilized. For instance, hydropower development has recently been hampered by a host of legal restrictions, including environmental compliance measures, and institutional barriers in the licensing process. Indeed, legislation has been proposed that would seriously diminish the potential contribution of hydropower for environmental reasons, despite the relatively benign environmental impacts of this mature renewable resource.

The modular nature of most renewable energy technologies allows energy supply additions to be made in smaller units than is common for conventional technologies, an advantage when energy demand projections are uncertain and the financial risks associated with the construction of large generating plants are high. Shorter lead times for adding these modular increments can reduce uncertainties in planning and allow incremental capital outlays, thereby reducing risk. Renewable electric technologies like those at LUZ show that the advantages of mass production can compete with the economies of scale enjoyed by large central station plants.

Among newly developing renewable technologies, the geothermal hydrothermal resource has led the way in electric power production. In 10 years, installed geothermal capacity has risen over 400%, from 608 MW in 1978 to 2,440 MW by the end of 1988. The California Energy Company has been particularly successful in integrating geothermal energy into utility power grids. According to Charles Condy, Chairman and CEO of the California-based company, the recently discovered Coso field in the Mojave Desert may be "one of the most significant energy finds of recent years." Initial estimates by the company suggest the Coso field can support 650 MWe of geothermal power for the next 30 years.

The DOE solar thermal electric program has been instrumental in supporting the developing systems which can provide electricity at utility-scale power levels. Almost 200 MW of on-line capacity is currently available at the previously mentioned LUZ facility, also located in the California desert, and projections indicate by the mid-1990s, an additional 400 MW of solar thermal capacity could be made available. These potential contributions would not be possible without advances in parabolic trough systems which can trace their technological origins to Sandia National Laboratory here in New Mexico. These trough systems encompass several new features, including enhanced receiver coatings, accurately shaped glass reflectors, and rotary joints for fluid transport. Current systems now offer an annualized delivered energy cost of less than 12 cents per kWh, which is within the "range of competitiveness" of utility peaking requirements. The program's cost goal is between 6 and 8 cents per kWh, an attainable mark which will satisfy additional utility baseload and intermediate power requirements.

Sandia has also been a key player in the development of solar thermal technology for use in the detoxification of hazardous waste—using concentrated sunlight to break down toxic chemicals into harmless components—a very exciting and promising new application. Sandia's long history of working well with industry has been instrumental in generating industry interest in this new area of technology.

Wind energy has also come a long way in recent years. The cost of electricity produced from wind, which in 1975 was approximately 50 cents per kWh, is currently between 8 and 15 cents per kWh in areas with highly favorable wind conditions. A total of 15,000 wind turbines nationwide have achieved a combined power rating of 1,400 MW and produce 2 billion kWh of electricity annually. This cumulative contribution is roughly equivalent to the typical output of a large-scale conventional power plant, and it is expected to grow in future years as costs are lowered.

In the buildings sector, the renewable R&D program is focused on reducing nonrenewable energy requirements in commercial as well as residential structures to maintain comfortable temperatures and humidity. Solar heating research activities include investigating high heat-capacity thermal energy storage materials that can be readily incorporated into conventional building products such as wallboard. Composite materials used in passive systems are capable of reducing the amount of additional thermal storage required to retain solar heat collected for nighttime applications.

This work builds on passive solar R&D pioneered in New Mexico and throughout the Southwest by a unique team of small architectural and construction businesses and researchers from Los Alamos and Sandia. The combination of the grass-roots efforts of the early passive pioneers here, who were largely responsible for solar greenhouses and the generation of a wide variety of passive system experiments, along with the modeling and design tools of Los Alamos, are still very evident in the field of passive solar today.

In the area of photovoltaics, utility contributions are currently small, but projections indicate that 100-300 MW of capacity could be available by 1995. The Electric Power Research Institute (EPRI) believes the attainment of unprecedented efficiencies recently achieved by solar cells which convert sunlight into electricity "may soon rival conventionally generated electric power in geographically favorable areas of the U.S." Here again, Sandia Labs and their contractors have contributed with important advances in PV cell efficiencies.

Electricity is only half the opportunity for renewable energy today. Transportation fuel is the other half, and some would say the more important half. Today the U.S. imports nearly half of the petroleum we use. Moreover, almost half of the U.S. trade deficit in 1989 was attributable to energy imports. The situation in the Persian Gulf has reaffirmed the unpredictability and volatility of world energy markets and the benefits of developing alternative fuels. Toward that end, the U.S. has been working in concert with other nations to develop alternatives and thus minimize the adverse effects of future supply disruptions. In addition to bolstering the Strategic Petroleum Reserve and encouraging the development of energy-efficient technologies, the U.S. has promoted the development of alternative and renewable transportation fuels. We are working aggressively on reducing the cost of producing ethanol from non-food feedstocks like trees and grasses, and we believe the cost of production can be reduced to a level that will be competitive with gasoline in the next decade. This would not only reduce our reliance on imported oil, with all of its consequences, but also would provide a powerful stimulus for development in rural America, with positive environmental benefits as well.

Finally, I might note that high-temperature superconductivity (HTSC) has the potential to revolutionize the transmission, distribution, and storage of electric power. U.S. participation in HTSC is spearheaded by DOE's pilot centers at three national laboratories: Argonne, Oak Ridge, and Los Alamos National Laboratory (LANL) here in New Mexico. These pilot centers represent an innovative experiment in cooperative research, and were deliberately structured to facilitate rapid response to changing R&D needs. In fact, the following expedited procedures are now possible under the legal framework governing pilot center R&D: immediate approval for contracts and projects; focus on product-oriented research; greater emphasis on transferring patent rights to industrial partners to speed commercialization; industry input provided by an industrial oversight committee; point of contact for companies seeking alliances with the national laboratories regarding HTSC research; and increased liaison among the national laboratories and pilot centers to facilitate cooperative research.

Renewable energy will continue to augment U.S. energy supplies as technologies become technically and economically more competitive with conventional, commodity-based energy systems; however, for market penetration to occur on a significant scale, renewable energy producers must aggressively pursue market opportunities and end-use applications which satisfy multiple energy requirements. As the current situation in the Middle East makes clear, we must continue to promote indigenous alternatives such as renewable energy.

While fossil fuels are finite, development of renewable energy resources is limited only by the state of our current scientific knowledge, technical expertise, and operational experience. Their potential is theoretically infinite. We are counting on our national laboratories here in New Mexico along with SERI, the Solar Energy Research Institute, to carry out our programs of research and development.

Senator BINGAMAN. Thank you very much. Let me ask you a few questions here.

On the National Energy Strategy, I raise the point with Henson Moore at the hearing we had there in Washington about the lack of any sense of immediacy about the problem. As you point out, the President called for this in July of 1989. I compliment him for recognizing the importance of doing something. We are going on to a year and a half since that was called for. As I understand it, the original time frame or time schedule for getting something to the Congress is still in place, which would be sometime next April we would get something presented to us.

I urged Henson Moore that if there was a way to do it, we ought to get something pulled together here and make sense out of it so the President can present it to Congress when we start in January at least. Because of the situation in the Middle East, I would think that would build enough political concern and enough public awareness that we have a much better chance of going somewhere with some of these proposals if we strike while the iron is hot. I do not know what is going to happen in the Middle East between now and April. I hope the situation resolves itself.

What do you know or what could you tell me about the possibility of moving up the time frame for issuing this National Energy Strategy?

Mr. DAVIS. I have to answer that in two parts, if I might. The first part is the process of actually delivering options to the President, and that will be done in early December as we said it would be, and we are on schedule to do that. There certainly was an internal look at Secretary Watkins' direction and Deputy Secretary Moore's direction to do every possible thing we could do to accelerate that process. But they also were willing to stay the course. They were willing to say that very clearly to avoid the risk of bringing forth options that are not well thought out; to avoid the risk of bringing forward options that, indeed, somebody might act on and produce unintended consequences.

So if we can move our work in DOE forward faster, that is fine. But we certainly have looked at it internally, and I think what it has caused us to do is to be even more careful in how we develop those measures so that when they are delivered, they will be well thought out and well founded. That will happen in early December.

I cannot speak for how long it will take the Administration to review those, and when the Administration will then decide on those measures along with our 1992 budget. The Energy Department 1992 budget certainly will be an important part of that, along with the decision when to release the strategy document to Congress. That is the second part of your question which I really cannot address. I would hope with you that it is soon, but my concern is that the Department of Energy has done the best possible job it can. I think we are well on our way with that. I think that the options we have developed, if those options continue to progress, will be fairly broad and fairly well balanced—a package which you can act on.

Senator **Bingaman**. Let me ask on the issue of what the Government can do, what the Department of Energy can do, to move this technology into practice. I think that is the phrase that you used. That is an issue we deal with not just, of course, in the area of transition technology that relates to our energy needs, but transition technology generally.

Could you pick a specific technology, photovoltaics, for example, or perhaps another, and tell me how, as you see it, the Department of Energy should be assisting the private sector and to assure that we actually have some domestic production of those technologies? That we are not totally dependent upon the foreigners to produce it.

Mr. **Davis**. I think photovoltaics serves as a good example. In January of 1990, DOE announced an initiative in photovoltaics, and we referred to it as "manufacturing technology." The idea there was to get right at the point. We have achieved efficiencies in photovoltaics conversion technology in the laboratory. They are almost mind boggling.

I go back about 20 years in this area, and I can remember some of our wisest people saying if we could ever produce a 15-percent-efficient photovoltaic cell, we could control the world. We have 30-percent-efficient cells operating at some laboratories here that are very close to home. So the scientific base is terrific. Our national laboratories have had a lot to do with that, very fundamentally important to that issue.

So in getting back to your question, what is the next step? We said what would be helpful is for the Government in this case to go to industry and say, "Okay. What is it going to take to move science into practice?"

Industry came back to us—this is the industry-driven aspect of it—and said, "What we think would be helpful is basically a consortium to identify the problems we have in manufacturing this technology, so that we can get from just a very small scale in individual pieces to where we can turn this out of the factory 24 hours a day."

So we put together a manufacturing technology initiative and we requested funding. In fact, we have reprogrammed some of our own funding to get under way. We wanted to reprogram our own funding, frankly, before we asked anybody else to assist us. That is an industry-driven project. We will continue to support that, and we will get at the heart of making our own industry better at manufacturing products so that they are more competitive both nationally and internationally.

Senator **Bingaman**. Let me ask what the time frame for this manufacturing technology initiative in the area of photovoltaics is? When was that set up? When do you expect some concrete result from it? Is this a 5-year project? Is this a 2-year project? What are we looking at?

Mr. **Davis**. We announced it in January and along with that we put forth a reprogramming request to Congress that was necessary. We, in some regards, did not even wait for approval for that reprogramming issue. That happened in early August, interesting enough. But we proceeded in other work necessary to commit funds when approval was obtained. We went through the necessary process in terms of the procuring and soliciting ideas from industry. We have their responses in hand now. We are actually under way with respect to defining those particular manufacturing processes that the industry wants to work on. Now we are ready to engage in the larger effort, and we have gotten, of course, approval to spend the money.

So the initiative is underway. In terms of seeing results, I think we are probably a year to a year and a half away from being able to point to actual machinery that is expected to produce product. And I think we are probably 3 years away from seeing a marketplace impact from that machinery.

Senator BINGAMAN. In the information I have been given here is that in the 1991 budget the administration asked for $43 million, Congress approved $46.9 million, for photovoltaic research and development. I do not know if that squares with your numbers.

I guess the real question is: How much of this goes to this so-called manufacturing technology initiative that you are talking about?

Mr. DAVIS. It is roughly $9 million in 1991.

Senator BINGAMAN. It will be $9 million. How much to reprogram in 1990?

Mr. DAVIS. We reprogrammed $1.5 million, basically, to get started on that in 1990.

Senator BINGAMAN. Will it be identified in the budget?

Mr. DAVIS. Sir, it is identified in terms of in our reprogramming documents that we put forth. We have identified exactly where the money was, where it was coming from, and it will be tracked in the accounting system that way. You will be able to see the full funding implication that goes to that initiative.

Senator BINGAMAN. Let me ask about this sale by Arco, Arco Solar. As I understand it, Seimens, a German firm, purchased the Arco solar photovoltaic business. We really did not see any action by the Department of Energy in response to that. There was some talk that there were some very significant technologies there that were essentially lost to a domestic manufacturer with that sale.

Is that something the Department of Energy could have acted in, should have? What is the situation? Is that not a concern?

Mr. DAVIS. Well, actually that is one I had some personal involvement in, and I just feel a little bit sore about it. We have acted substantially in that regard. In terms of the Department of Energy's position, it was that actually we argued against the sale, and there is actually a process already established where those kinds of issues are reviewed.

Senator BINGAMAN. Is this CFIUS?

Mr. DAVIS. Yes. I have trouble pronouncing that. It sounds so disgusting I do not like to use the word. But let me tell you, the process is even worse.

Senator BINGAMAN. This is the thing under the Treasury Department where they pass on whether or not acquisitions of U.S. firms by foreign firms are a threat to the national security; right?

Mr. DAVIS. Yes, sir. I engaged in that process and took it through the various steps that were open to me, and finally took it to the final hearing, and I was basically handed my hat. We pressed the issue vigorously. We were simply not able to prove beyond a reasonable doubt that, indeed, this was a threat to our national security, because, in fact, it is one of our economic trade partners. I think the general view largely driven by our economic agencies, was that indeed in the overall world economic scheme of things this was a positive thing to do and not a threat to our national security. I do not happen to see it that way. I think it is a threat to economic security.

Senator **Bingaman**. As I understand it, they have considered several hundred of these and found the threat to the national security in two or three.

Mr. **Davis**. I can certainly say that I was not successful in the process.

Senator **Bingaman**. Let me ask about a bill we passed and the President signed called the Renewable Energy and Energy Efficiency Technology Competitiveness Act. What is being done to implement that act? I gather you have sent out proposals for joint ventures. What has the response been to that solicitation?

Mr. **Davis**. We have a couple of specific things we have to do there. We are required to solicit for joint ventures in specific technologies. We are also required to put together an advisory panel to help us execute that program. And in response to that we have done three things: we have solicited interest in terms of what might be of interest to the private sector; we have begun to form the advisory committee; and we have developed that proposal as to who the people would be and are moving that forward within the Department of Energy.

We have done one other thing, and I think this is very important. If you look within the conservation program now, we restructured that organization in a rather fundamentally different way, and we are trying to leverage a substantial amount of money that used to be in what was called the State and Local Programs area which people refer to as the Weatherization Program. There are monies appropriated for weatherization. There are monies available for that program through petroleum violation escrow accounts. It is basically money that flows to the States, and there is a substantial amount of money available that has been committed by the States, but not necessarily spent.

Working directly with a number of States, we see that they would be very interested in participating in a number of joint ventures and would be willing to bring some of this money to the table because it means economic development to them as well. So we have taken a little broader view. We have actually worked internally to come up with an approach that covers rules for joint ventures in general and be in a position so that each one is not a new venture. We expect to actually do more than just the five described in the law and we expect to do them more as a matter of routine as opposed to being directed in specific areas.

I think we are moving along reasonably well. We are not going to hold up the joint ventures because of appropriation issues. As far as I am concerned, we have gotten direction, and we will do it.

Senator **Bingaman**. That is great. Let me ask about one entity here, and then I will defer to Senator Domenici to ask questions.

I am informed there is a committee on renewable energy commerce and trade in the executive branch. I am not familiar with what the committee's track record, accomplishment is. How often it meets. How significant a factor it is.

Could you just inform me as to where this fits in the overall structure of things? Whether it is useful or whether it needs to be revitalized? What has happened?

Mr. **Davis**. It is a small activity, again within my part of the Department. You might actually view it as a small guerrilla warfare attempt by a number of very dedicated people that decided there is, indeed, an opportunity to export renewable technology to various places in the world. They realized there are many Federal agencies that hold a lot of keys to export programs; AID, Export/Import Bank, various financing entities, various groups with international responsibilities.

And essentially, at the working level, these people have been able to put together a group that can actually bring the right international viewpoints and sources of financing together for some of our renewable industrial participants. And they have worked this along without much assistance and without a great deal of recognition. We have essentially raised the process up.

At the same point in time, Deputy Secretary Henson Moore has moved aggressively with respect to the overall Department in saying that assisting American industry to export energy technology is a very good thing to do, and he put his weight behind it. We have really kind of connected the two together. You will see us move more and more aggressively in renewable energy exports. It was recently announced we have an Deputy Assistant Secretary for Energy Exports.

So our direct activity is going to continue. We focus on renewables as well as energy efficiency, and we are indeed requesting more money for our portion of those activities. I think it is a very important opportunity. I think it does need additional review by you all, and I think it will merit additional support.

Senator **Bingaman**. Thank you very much.

Pete, why don't you go ahead?

Senator **Domenici**. Thank you very much.

Mr. Secretary, before we talk about strategy and R&D, let me just talk a minute with you about two things you are in charge of that we are doing in our State; waste minimization is within your particular jurisdiction and superconducting material centers, including the one at Los Alamos.

I hope that as you proceed through pursuing research and development in any area that is supposed to ultimately affect our lives and our activities, that the past decade will show you one thing—and I am just going to make it as my own observation, and you can see it alive in the superconducting center—frankly, I believe the sooner you get the industry sector involved in pooling research and being participants in research, the better chance the American people have of getting something added to the product line or to the market from the expenditures of money.

I think we were kind of frightened about that concept for a while. Our laboratories were almost cultured to be leery of it. They are no longer with the technology transfer emphasis, and the fact we do all the research. Nobody steals anything from us. They just make the product, and we do not.

It seems to me when you are going to start down the line, you look at the superconducting center up there, you will find one very small American company, a couple of medium size, a couple of large that are on board, and they talk with all the scientists and put up money, so it is not going in the direction that may have no application whatsoever.

I think photovoltaics has had marvelous success, but I think it would have been much, much more effective for our country had the user side been involved in the research side much sooner. I compliment you for doing it now.

I think the waste minimization is moving in the direction now of bringing in the industries, large and small, who have ideas about applications into these projects so that there is not the big lag time between the research and using it. I just would appreciate your thoughts on that and your observations. Perhaps I am not right, but I see it in our labs now, and they are very excited about it. I hope you are.

Mr. DAVIS. You are right and I think I can back that statement up with some examples. Part of my testimony highlights the success of the superconductivity pilot centers at Oak Ridge, Argonne, and here at Los Alamos. That is success, and we have reflected that success in terms of our budget requests. That success is exactly what led me to believe that our approach on waste minimization is right on the mark. We are going to start that right up front. We are developing a program by linking our laboratory scientists with leaders in the industrial sector, and they are bringing to us—not vice versa—topics that are important, things they want to work on, and recommendations on how they want to structure the relationship. That is further accelerated by the fact that now we have some law in place to make that whole contractual process much more efficient.

I think we have been able to take advantage of some demonstrated successes. Waste minimization is generally in the same vein, but I have great expectations for that program. There will be some budget implications there, but I think we are ready to step up to that. Recently there was an important agreement signed with General Motors and Los Alamos on fuel cells. Another example of the right relationship between Government science, and industrial science and production capability.

General Motors, Ford, and Chrysler are about to bring forward a battery consortium. When they do that, we are going to identify right back to them various facilities, various individuals from the national laboratory structure that have an interest and want to work in the area. When they finally sort out what it is they want to do, then DOE, as a minimum, is going to fund the Government side of that. We are going to facilitate that process by making facilities, personnel, and expertise available to them. That is the direction we are going in predominantly. That is going to be the rule and not the exception.

Senator DOMENICI. Senator Bingaman raised the issue of that energy strategy and quite properly asked about the timeliness. I have been around long enough where I would be careful, although I would take his admonition. I remember President Carter sending us an 8-point energy plan in a hurry, and the whole thing got turned down in 1 month by Congress. No aspersions on either Congress or the President. That just went down the drain.

But let me ask you: What is this energy strategy supposed to be? What goal are you working for? Is it going to be a voluminous set of recommendations? Is it energy independence? Is it cut our dependency in half? Just what is its basic premise?

Mr. DAVIS. The original challenge that was issued by the President had some themes to it, and two of the themes were pretty clear. One was reduce our dependence on imported energy. Along with that was rely to the extent possible on the market forces to do that. Well, that is okay for the President to say, obviously. I mean I do not comment on that one way or the other. The challenge is how you translate that into action. How do you get from a general approach to very specific things? That has been difficult for us to do, because during the first 9 or 10 months, the only people we heard from were what I refer to as the "energy hard core," and only then because of the environmental concerns, nobody else was interested.

Senator DOMENICI. What was that statement?

Mr. DAVIS. Nobody was interested. We would go around the country basically, and we would get input and we would get direction from what I refer to as the "energy hard core," people who understand the issues and really understand how fundamentally important these things are. I will guarantee you there was no large public interest. There was not. Now suddenly we have another little wake-up call and suddenly there is a great deal more interest. I, like you, hope we can capture that and put some policies in place with enough duration for them to actually be effective.

How we structure this thing and what we actually set up as goals are very important. The structure for the strategy has not been developed yet. What we have done is identify a whole series of options, and for each of those options we have tried to be specific about exactly what the action is, so that it is clearly and accurately stated and understandable. We have defined what the pros and cons are for each particular action, so that they are fair. So that policy makers like you can review them and understand what that particular action taken individually will mean. We have tried to do the analysis on each of those consistently, so that you can see the economic impact; you can see the environmental impact; and if you chose, you can see the impact on energy security option by option by option.

Well, I do not think anybody wants to look at a thousand different options. But now that we have developed options in a fairly consistent way, we can start to bundle them. We can start to look at the impacts of a number of those options by sector of the economy. What do you do in the transportation sector that is 98 percent dependent upon oil? What do you do in the utility sector? It is 5 percent dependent on oil. What do you do in the industrial sector? It is one-third electricity, two-thirds fuels and a big piece of feed stock that is also energy.

These options now are in the process of being bundled, and they are being played up against each of the sectors in terms of what is the cost, and what is the energy impact. I think when you see that structure after the first of the year, then you will be in a position to say, depending on what we want to do in terms of economic growth and environmental impact in each sector of the economy, here are the research, regulatory, and legislative policy options that we can employ. Which ones do we actually want to adopt for the near term, midterm and long term. This has not been presented publicly yet, but I am guessing about the structure it will take so that each of these options become useful to you.

Senator DOMENICI. Thank you very much.

Senator BINGAMAN. Thank you very much.

We have two other distinguished panelists here. Although I could ask additional questions, and I am sure that Senator Domenici could, too, why don't we go ahead and thank you for your presentation and move on to the second panel at this time. Your responses have been very useful.

Mr. DAVIS. Thank you very much.

Senator BINGAMAN. Thank you very much.

Our next two panelists are representatives from the national laboratories. Dr. John Whetten is Associate Director for Energy and Technology at Los Alamos National Laboratory, and is a biologist by training. Dr. Virgil Dugan is Acting Vice President at Sandia National Laboratory and has a doctorate in electrical engineering.

Dr. Whetten, would you like to go ahead first? Be sure that microphone is pointed at you properly so that people in the back can hear.

STATEMENT OF DR. JOHN T. WHETTEN, ASSOCIATE DIRECTOR FOR ENERGY AND TECHNOLOGY, LOS ALAMOS NATIONAL LABORATORY

Dr. WHETTEN. Thank you very much, Mr. Chairman.

I am very pleased to have been invited to participate in this hearing on the status of new energy technologies.

As you know, Senator, Los Alamos National Laboratory has been engaged in developing new technologies for energy, supply, use and conservation for many years. We are also involved in environmental research, and we have been placing increasing amount of emphasis on our interactions with industry to improve our nation's economic competitiveness.

Indeed, we now find that these three areas—we call them the three E's, energy, environment and economic competitiveness—are really very closely linked. All, for example, are tied to the problems of a New Mexico independent oil producer who is struggling to enhance the productivity of his oil field; the public's concern about greenhouse gases and the climate change believed to be caused by energy use, and the need to develop new sources of energy that are reliable and affordable and environmentally acceptable.

In my written statement I have cited a number of examples of technologies that we are developing. Again, it is very difficult to say whether these are related more to energy, or to environment, or to economic competitiveness, because really all three are involved.

But this morning I would like to discuss, just a couple of minutes each, three examples which I cite in my written testimony. One is dealing with improved oil recovery. The second is one that we spoke about already through your discussions with Mr. Davis, the waste minimization in industry, and thirdly is the hot dry rock geothermal energy program.

First, the improved oil recovery. In 1988 the Department of Energy joined Los Alamos National Laboratory, Sandia Laboratories, and the petroleum industry in a collaborative effort to increase oil production in the nation's oil fields. Because oil production is a traditional but declining part of New Mexico's economic base, improved oil recovery in New Mexico could mean a significant economic boost to the State.

The partnership allows us to quickly transfer technologies developed for defense and energy programs at the laboratories to the petroleum industry. For example, the first Los Alamos test, under partnership auspices, was with the Murphy Operating Corporation, a small New Mexico independent located in Roswell. We conducted this experiment in the Chaveroo field in the Permian Basin of Eastern New Mexico, and did some seismic activity to better define the reservoir. If our preliminary results are confirmed, 8 million to 10 million more barrels of oil could be recovered from this field alone through more effective use of it. A very important feature of this test, one that was made possible by the structure of the partnership itself, was that we were able to be in the field with Murphy Operating Corporation very quickly, within 5 months after our initial contact.

Our second experiment was a test of crosswells seismic imaging technology in McKittrick field near Bakersfield, California, which involved a number of larger corporations; Texaco, Chevron, Amoco, Exxon, Stanford University, all cooperating under the leadership of Los Alamos. This technology is somewhat analogous to medical CAT scans but uses acoustic waves instead of X-rays, and is on a scale appropriate to an oil reservoir. The field test resulted in an image of a fault which showed a large bypassed accumulation of heavy crude oil. We understand that Texaco is now going after that target, which may be an excellent one for enhanced oil recovery.

The reason for mentioning this oil recovery technology partnership is that it provides us, we think, an excellent model for interacting with industry in many of our energy and environmental programs. And our early successes suggest that we really may be able to make a difference, both to the nation's energy supply and to the economic well-being of our collaborating companies.

The next example that I would like to cite is the waste minimization in industry activity. This is again with Los Alamos and Sandia working with the three research universities in New Mexico where we are actively working with the Department of Energy to create a new program called the Industrial Wastes Materials Reduction Program, to develop partnerships with industry in cost-effective-waste-reduction technologies and practices. This program will target waste reduction opportunities that offer significant savings in energy, costs, and materials while achieving environmental benefits.

A key element of the program strategy is to reduce waste generation upstream rather than dealing with the waste at the other end of the pipe, where one then has a great deal more environmental cleanup problems. The estimated potential savings from reduction of industrial waste is huge, perhaps enough to satisfy the energy needs of some 30 million American homes.

For example, on the electronics and aerospace industries organic solvents are used to clean parts and circuits. The use, handling and disposal of these resulting wastes is an increasing concern for both public health and the environment. Prior work with supercritical water at Los Alamos and Sandia, primarily in support of DOE's weapons complex, has indicated that this technology may be a cost-effective and energy-efficient way to clean up toxic organic materials. Several companies have already expressed a strong interest.

Another example, the production of space age graphite fiber/epoxy composite materials for engineering application today generate a significant amount of waste. Senator, did you realize that 85 percent of the composite goes into waste and is not used? A systems approach to the entire manufacturing process and the application of diagnostics and controls to individual stages of the process will reduce waste, saving both energy and materials.

Final example I would like to cite is with the hot dry rock geothermal energy program. This is a program which I am sure you have heard about before. It has been supported by the Department of Energy and its predecessor agency since 1973 with Los Alamos National Laboratory leading the research at our experimental site at Fenton Hill just west of Los Alamos. This, Mr. Chairman, is the technology that could be commercialized in a few years as a new source of energy, and has no significant adverse environmental affects.

Let me explain just a moment how it works. Using conventional oil and gas fracturing techniques, a volume of rock is fractured that is hot below the surface of the earth. Wells that are drilled into this fractured hot rock can both introduce cold water, which is then circulated throughout the reservoir where it becomes heated, and then serve as a production well from which the water can exit the reservoir and be moved to the surface. The heat is then removed and used to produce electricity or for industrial process heat. The resource is enormous, and because the system is closed there are no emissions or waste products.

The hot dry rock energy extraction system is a wholly American idea, proven in concept by the DOE program at Los Alamos. However, without some careful attention, the dividends of this program will certainly go the way of the television, the VCR, or the semiconductor. For the United States is not the only Nation developing hot dry rock. The United Kingdom has a much larger program. Both Japan and Germany have contributed to the United States program through an IDA agreement. Japan is committed to an aggressive fast-track R&D program in an attempt to overcome the lead the United States currently has. The Soviet Union has two large R&D programs. The French and Germans are now united in their own program.

The reason for this is once again because of the three E's: it is a new source of energy; It is environmentally sound; and it makes sense businesswise. The latter is confirmed by economic analyses from Los Alamos, the Electric Power Research Institute, Bechtel National, Inc., the United Kingdom, and Japan all show that electricity from hot dry rock should be competitive with other energy sources at 5 to 7 cents per kilowatt hour at the busbar.

Because of the geological environment required for hot dry rock systems, Los Alamos National Laboratory has worked with well service companies to advance well drilling, fracturing, and completion technologies as well as new tools and techniques for logging and reservoir assessment. In some cases our collaborations have resulted in improved or new products such as drill bits and packers. Recently some of this technology is being transferred to the oil industry, as I indicated earlier in my discussion of the oil recovery technology partnership.

The Los Alamos experience with hot dry rock geothermal energy has proven virtually no adverse environmental affects of the technology. In addition, the accessible resource is worldwide and huge, perhaps on the order of 100 to 1,000 times the worldwide resource for fossil energy. Therefore, once issues concerning reservoir lifetime and heated extraction rates have been answered, it could be an ideal energy technology for developing countries. This demand would open up U.S. industry export markets for the technology itself, and provide international opportunities for the U.S. oil service companies. For example, it has been estimated that a typical 50-megawatt power plant could provide on the order of $50 million in business for the drilling and the service industry.

In conclusion, Mr. Chairman, we have developed and are developing a number of environmentally acceptable technologies. To us the three E's are important in this and inexorably linked; energy, environment and economic competitiveness. This is sort of our theme song as we look to the future in energy technology development. The technologies that we have developed from the extensive technology base that exists at our laboratory and others is the result of both defense and energy programs. We think it is important the Nation capitalize on this.

We are forming an alliance with industry and universities to assist in the development of new technologies. These alliances should benefit New Mexico and the Nation through the development and utilization of our energy resources and contributing to new business opportunities for industry.

Thank you very much.

[The prepared statement of Dr. Whetten follows:]

PREPARED STATEMENT OF JOHN T. WHETTEN, ASSOCIATE DIRECTOR FOR ENERGY AND TECHNOLOGY, LOS ALAMOS NATIONAL LABORATORY

Mr. Chairman, I am pleased to have been invited to participate in this hearing on the status of new energy technologies.

As you know, Los Alamos National Laboratory has been engaged in developing technologies for energy supply, use, and conservation for many years. We are also involved in environmental research and development (R&D) and have been placing increased emphasis on our interactions with industry to improve our nation's economic competitiveness.

Indeed, we find now that these three areas—energy, environment, and economic competitiveness—are inexorably linked. All, for example, are tied to the problems of a New Mexico independent oil producer struggling to enhance the productivity of his oil field, the public's concern about greenhouse gases and climate change believed to be caused by energy use, and the need to develop new sources of energy that are reliable, affordable, and environmentally acceptable.

To solve such problems, extraordinary cooperation among technology developers, the private sector, and public policy makers will be required. As a technology developer, Los Alamos is committed to developing environmentally acceptable energy technologies in collaboration with the private sector and universities.

In my testimony this morning I would like to focus on the contributions Los Alamos can make in developing technologies to use energy more efficiently and create additional energy supplies. I will cite some examples of technologies that are available in the near term, some we are working on for the mid-term (5-15 years) and some that are in stages of research that may make them available in the long term (>15 years).

NEAR-TERM TECHNOLOGIES

Improved Oil Recovery—The Oil Recovery Technology Partnership (ORTP), established in the fall of 1988 by the Department of Energy, joins the Department of Energy (DOE), Los Alamos and Sandia National Laboratories, and the petroleum industry in a collaborative effort to increase oil production in the nation's oil fields. Because oil production is a traditional—but declining—part of New Mexico's economic base, improved oil recovery in New Mexico could mean a significant economic boost to the State.

The Partnership allows us to quickly transfer technologies developed for defense and energy programs to the petroleum industry. For example, the first Los Alamos field test under Partnership auspices was conducted last summer in collaboration with Murphy Operating Corporation, a New Mexico independent producer. Conducted in the Chaveroo field in the Permian Basin, the test indicated sharp increases in seismic activity correlating with production operations. This test demonstrated that microseismic fracture mapping may be a useful tool for improved oil recovery. If our preliminary results are confirmed, 8 to 10 million more barrels of oil could be recovered from the Chaveroo field alone through more effective waterflooding and in-field drilling. An important feature of this test—one that was made possible through the structure of the Oil Recovery Technology Partnership—was that we were in the field with Murphy Operating Corporation very quickly (five months) after the initial contact.

Our second field test was a test of crosswell seismic imaging technology involving Texaco U.S.A., Chevron Oil Field Research Company, Amoco, Exxon, and Stanford University under the leadership of Los Alamos. The technology is somewhat analogous to medical CAT scans but uses acoustic waves instead of X-rays and is on a scale appropriate to an oil reservoir. The field tests, which were conducted in Texaco wells in California's McKittrick field, resulted in an image of a fault which showed a bypassed accumulation of heavy crude oil. Texaco donated five wells to the project, deferring production from them for two months. *Advanced Technology Week* reported, in the April 16, 1990, issue, that Texaco plans to test the apparently bypassed pool, which is a prime target for enhanced oil recovery operations.

Another Partnership field test was conducted by Sandia National Laboratories, working with another New Mexico independent, the Harvey E. Yates Company, in the Bone Springs Formation of the Permian Basin. The goal of this effort is to improve oil recovery from low-permeability reservoirs that may have natural fractures. The collaboration is focusing on determining whether natural fractures exist and, if they do, on what effect they could have on production.

We believe the Partnership provides an excellent model for interacting with industry in many of our energy and environmental programs, and our early successes suggest that we may be able "to make a difference"—both to the nation's energy supply and to the economic well-being of our collaborating companies.

Waste Minimization In Industry—Los Alamos and Sandia are actively working with the Department of Energy to create a new program, called the Industrial Waste Materials Reduction Program, to develop partnerships with industry in cost-effective waste reduction technologies and practices. This program will target waste reduction opportunities that offer significant savings in energy, costs, and materials while achieving environmental benefits. A key element of the program strategy is to reduce waste generation upstream rather than "end-of pipe" cleanup of environmental problems. In this way, waste reduction and savings are synergistic. The estimated potential savings from reduction of industrial wastes is one to four quadrillion BTUs per year—enough to satisfy the energy needs of 30 million American homes.

The electronics and aerospace industries currently use organic solvents to clean parts and circuits. The use, handling, and disposal of these resulting wastes is an increasing concern for both public health and the environment. Prior work with supercritical water at Los Alamos and Sandia, primarily in support of DOE's weapons complex, has indicated that this medium may be a cost-effective and energy-efficient way to cleanup toxic organic materials. Several companies have expressed a strong interest in the potential use of this technology.

The production of "space age" graphite fiber/epoxy composite materials for engineering applications today generates significant waste. Approximately 85% of the input fibers and epoxy are ultimately discarded as waste. A systems approach to the entire manufacturing process and the application of diagnostics and controls to individual stages of the process will reduce this waste, saving both energy and materials.

A more broadly applicable approach is process diagnostics and controls. The broad expertise developed in DOE's national laboratories, to diagnose and control such disparate processes as coal gasification and prototype novel internal combustion engines, has already proved useful in specific commercialized instruments. This base of expertise is increasingly recognized by American industry as a resource for better industrial process control, contributing to reduction of costs, energy use, and waste.

This proposed program will be driven by industry's needs and commitment leveraging federal research and expertise with industry's internal efforts to codevelop technology that is valuable to numerous companies and industrial sectors. A vigorous education and outreach effort will extend the benefits to companies not directly participating in the program (particularly small businesses). We anticipate significant technical benefits to the government, e.g., for the nuclear weapons complex.

Coal—Both New Mexico and the United States as a whole are richly endowed with coal. It is our nation's most abundant energy resource. Improved technologies can be applied to preparation, improved modeling, and control of combustion processes for gains in efficiency and pollution control and in supporting technologies including instrumentation and materials. Upgrading the energy content of the low BTU coals could enable greater coal exports, thus helping the national balance of payments problem while supporting an important industry.

An example of a Laboratory technology that could improve the combustion of coal is combustion modeling, which can help reduce environmental emissions. Los Alamos is a leader in the field of computer modeling of combustion and in developing advanced multidimensional, multiphase, reactive flow computer programs for the analysis of practical combustion systems.

KIVA II is the most recent in a series of computer programs that have been developed at Los Alamos for analysis of the complex phenomena that take place in automobile engines and other combustion systems. Every major automotive manufacturer has a copy of KIVA. KIVA II, the latest version of the code, is being used for engine design by General Motors. It is being used to predict many trends in automotive engine performance and to gain physical insight into in-cylinder flow fields. In addition to internal combustion applications, KIVA II is being used to simulate flows in stationary spray and coal slurry combustors. A national KIVA users group has been formed to facilitate use of KIVA II, to encourage communication between users, and to identify important issues for code development.

Global Change—Los Alamos has a large integrated program in all phases of global change studies. We are involved in supercomputer modeling of the oceans and atmosphere and their interactions with land, coupled with an experimental/observational program. Two areas of emphasis are the development of advanced computer models that simulate the earth's climate and the use of an existing global circulation model to study the distribution and movement of man-made contaminants (e.g., chloroflourocarbons, carbon dioxide, and methane) in the atmosphere. Our goal is to develop a comprehensive understanding of ocean atmosphere dynamics so we can provide support for national initiatives in energy production that involve the climate. We believe that a good scientific base in understanding global climate is necessary before policy decisions are formulated.

As an example of current environmental R&D related to global climate, we are collaborating with the Mexican Petroleum Institute to characterize and model the air pollutants in Mexico City. The three-year study will develop remediation options for improving air quality in the Mexico City area.

MID-TERM (5-15 YEARS) TECHNOLOGIES

Hot Dry Rock Geothermal—The hot dry rock (HDR) geothermal energy program has been supported by DOE since 1973, with Los Alamos National Laboratory leading the research at our experimental site at Fenton Hill, 35 miles west of Los Alamos. After completion of a phase-one system at a shallow depth, where we demonstrated technical feasibility, a well was drilled into hot, competent, basement rock. Using conventional oil and gas fracturing techniques, a man-made geothermal reservoir was created. The formation of the reservoir was monitored with sensitive microseismic instrumentation and software developed through the program. Using this information, a second well was drilled to connect to the reservoir, mining heat from the rock, and returned to the surface through the second well. We operated for thirty days and now we are preparing for a one-year test of the system. In a commercial HDR application, the hot water can be used to produce electricity or for industrial process heat. The system is closed and there are no environmental emissions.

The HDR geothermal energy extraction system is a wholly American idea proven in concept by the DOE program at Los Alamos. However, without careful attention, the dividends of the DOE program will certainly go the way of the semiconductor and the VCR. The United States is not the only nation developing HDR. The United Kingdom has a much larger, although currently slower-paced, program than ours. Both Japan and the Federal Republic of Germany contributed to the United States program through an International Energy Agency agreement. Japan has committed to an aggressive, fast-track R&D program in an attempt to overtake the technological lead held by the United States. The Soviet Union has two large R&D programs. The French and the Federal Republic of Germany have also recently initiated an R&D program. Economic analyses by Los Alamos, Electric Power Research Institute, Bechtel National, Inc., the United Kingdom, and Japan all show that electricity from HDR should be competitive with other energy sources (5 cents to 7 cents per kilowatt hour at the busbar). However, the U.S. program is the most technologically advanced and presently leads in being closer to commercialization.

Because of the geological environment required for HDR systems, Los Alamos National Laboratory has worked with well service companies to advance well drilling, fracturing, and completion technologies as well as new tools and techniques for logging and reservoir assessment. In some cases, our collaborations have resulted in an improved or new product such as drill bits and packers. A company, Hot Hole Instruments, Inc., spun off from the program to commercialize some of the logging equipment and to provide service to the geothermal, oil, and gas industry. Recently, Los Alamos has been working directly with the oil industry to apply other HDR-developed technology to enhanced oil recovery.

The Los Alamos experience with HDR geothermal energy has proven virtually no adverse environmental effects with the technology. In addition, the accessible resource is worldwide and is estimated to be 100 to 1000 times the worldwide fossil resource. Therefore, once issues concerning reservoir lifetime and heat extraction rates have been answered, it would be an ideal energy technology for developing countries. This demand would open up U.S. industry export markets for the technology itself and provide international opportunities for the U.S. oil service companies. For example, a typical 50-megawatt power plant would provide $50 million in business for the drilling and service industry.

Fuel Cells—Since 60 percent of this nation's use of oil is for transportation fuels, there is a need for an efficient, low-polluting, cost-effective, reliable and safe alternative to the internal combustion engine. For the past six years, Los Alamos has been conducting a research program on proton exchange membrane (PEM) fuel cells that have the potential to provide such an alternative. The PEM fuel cell offers the best combination of characteristics to meet these needs in small-scale and high-volume applications, such as transportation or small stationary applications. The goal of the Los Alamos program is to develop the technology to the point where commercial development is technically and economically feasible.

Substantial progress has included more than 30-fold reduction in platinum utilization, demonstration of densities of 1 Watt/cm^2 on hydrogen and air with low platinum loadings, the development of techniques to eliminate anode poisoning by carbon monoxide, and development of small-volume methanol reformers with improved efficiency and transient response. Recent progress has generated strong interest by the automobile industry including a major development program by General Motors Corporation in conjunction with Los Alamos.

LONG-TERM (>15 YEARS) TECHNOLOGIES

Fission Energy—Fission energy continues to offer the promise of an acceptable energy source for electricity for the long term, even though public acceptance of this technology is at or near an all-time low. The Laboratory supports nuclear energy development by focusing on reactor safety, development of specialized reactors for defense and space applications, and management of nuclear waste. Los Alamos is a major participant in the SP-100 program with a goal of demonstrating a compact nuclear power system for space applications. We help ensure reactor safety by conducting research in support of reactor licensing by the Nuclear Regulatory Commission. In July 1987 the Compact Nuclear Power Source (CNPS) was successfully tested. The new reactor design with low maintenance and low cost has potential as an energy source in remote locations. We are beginning a research effort in accelerator transmutation of waste with a long-term goal of changing the storage requirements of radioactive waste from thousands of years to hundreds of years. We also support the Yucca Mountain Project to provide a geologic repository for the storage of high-level commercial wastes. All of our R&D in fission energy is intended to provide new technology that is acceptable to the public, satisfies environmental, health, and safety requirements, and can be licensed efficiently.

Fusion Energy—Since the 1950s, Los Alamos has engaged in research related to controlled fusion, the process that powers the sun and stars. The reason for this long-standing emphasis is that fusion offers an attractive energy option for the long-term with essentially inexhaustible fuel and desirable safety and environmental features as an electrical power station.

The current role of Los Alamos in the nation's Magnetic Fusion Energy program is to contribute to the goal of demonstrating magnetic fusion as a practical energy source. Our main focus is on compact magnetic configurations, that might lead to relatively small and simple reactors compared with the mainline tokamak configurations.

We have been remarkably successfully with experiments in our ZT-40 device and are currently constructing a larger next-generation experiment, the ZTH, which will be the first experiment in the Confinement Physics Research Facility, currently under construction at Los Alamos.We have developed and are using the Tritium Systems Test Assembly, a unique world resource for tritium, to demonstrate the fuel cycle for fusion power systems and to develop the technology while evaluating advanced safety and environmental protection systems.

CONCLUSION

Los Alamos has developed and is developing a number of environmentally acceptable technologies dedicated to more efficient energy use and increased energy supplies. These technologies have developed from the extensive technology base that exists at the Laboratory as a result of both defense and energy programs. We are forming alliances with industry and universities to assist in the development of new technologies. These alliances should benefit New Mexico and the nation, through development and utilization of our energy resources and contributing to new business opportunities for industry.

Senator **BINGAMAN**. Thank you very much, Dr. Whetten.

Why don't we hear from Dr. Dugan also at this time before we ask questions.

STATEMENT OF DR. VIRGIL L. DUGAN, ACTING VICE PRESIDENT ENERGY PROGRAMS, SANDIA NATIONAL LABORATORIES

Dr. **DUGAN**. Thank you very much, Mr. Chairman, Senator Domenici, ladies and gentlemen.

We do appreciate the opportunity for Sandia National Laboratories to present our views on the progress which renewable energy has made over the last 20 years, and also our insights into what the futures for these technologies is going to be.

I have entitled my presentation today "Renewable Energy For Today and For Tomorrow," because I would like to make the point that renewable energy is a reality in today's economic climate. The technology is present in a way that it can be attractive in a commercial and a valuable sense. In addition to that, there are going to be great opportunities for advancement of many of these technologies.

As you know, Sandia is dedicated to enhancing the security, prosperity, and well-being of the nation; we work to apply the best integration of scientific and engineering creativity to achieve comprehensive, timely, and cost-effective solutions to our nation's most pressing problems.

Recognizing the national needs as well as the potential of renewable energy technologies, Sandia has been actively involved in developing solar thermal, solar photovoltaic systems, wind energy systems, geothermal technology, and advanced batteries, among others, since the early 1970's. Our optimism about the national value of these technologies continues to grow as the world's energy and environmental situation evolves, and as these technologies continue to advance.

In my presentation today I will emphasize both the status of some of these developments as well as a vision of the future opportunities based on current research and development efforts.

First of all, let me talk about renewables that are in place today and how they are making an impact in our energy economy, and relative to our environmental needs in our Nation today. Significant impacts and advances have been made in each of the areas of renewable energy development with which Sandia has been involved and major commercial installations of the Sandia developed technologies have been realized. There is one example of this, and in line with the comments that Mike Davis made earlier, solar thermal-electric technologies developed at Sandia in the 1970's and the early 1980's have resulted in several significant commercial power plant installations in Southern California. Specifically, the construction and continuing operation of the world's largest solar-electric complex of approximately 360-megawatt electric of hybrid solar thermal natural gas electric power systems was made possible using Sandia developed parabolic through technology. These hybrid solar/gas systems are capable of selling electricity at a cost of 8 to 15 cents per kilowatt hour, and in addition to that, an 80-megawatt electrical plant can be put on line in approximately 9 months.

Now, moving to photovoltaics, there are currently about 25 megawatts of electric power serviced by photovoltaic systems in the U.S. today, and there may be four or five times that available on a worldwide basis. These systems rely on crystalline silicon cell, module, system, and power remote electrical loads where high reliability in remote environments is critical or where connection to the electric utility is uneconomical. It turns out that New Mexico as well is benefiting greatly from this technology, from these types of applications. If you drive around Albuquerque or around New Mexico, you can see photovoltaic modules very visible on highway signs, water pumping, irrigation control systems, bus stop lighting, emergency telephones for highways, railroad crossing signs, rest stop power systems, tourist information radio systems, rural home power, and many other uses. I just found out last week there is one out just east of the canyon here on one of the forest service towers that I was not even aware of.

Wind energy also has played a large part in the development of Eastern New Mexico by providing the power source for water pumping and subsequent cattle raising on the eastern plains of New Mexico. Today's much improved wind energy technology is providing at least 1500 megawatts, one and one-half kilowatts of electric power to utility grids in this country as well as contributing to service such needs as water pumping in remote locations.

The first generation vertical axis wind turbine technology, which was developed here at Sandia, today represents about 100 megawatts of this total generating capacity. It is providing wind energy at a cost at less than 10 cents per kilowatt hour on sites in both Southern and Northern California and being considered at other locations around the country.

Sandia has been instrumental in development of drilling, logging, drilling fluid, and lost circulation technologies for the geothermal energy. The polycrystalline compact drag bit technology, which was developed for the geothermal industry at Sandia, has a worldwide market today for both geothermal and oil and gas drilling, and we estimate that the approximate actual value of this technology is on the order of $1 billion.

Now let me shift my comments from what is happening today and what contributions have been made to date to a view of tomorrow and how these technologies might progress and be even more important in tomorrow's economy. As we all know, a principal need is for society to view renewable energy options which are secure and not environmentally insulting as premium supply options, and to grade other supply options relative to this premium. This is going to require the full life-cycle cost of capital, fuel production, operating requirements, environmental affects, waste disposal, and system decommissioning be recognized and internalized in the selling price of energy from each option that might be considered.

From a technological prospective the key to success for renewable technologies are number one, that there be higher efficiency for collection and conversion. Number two, that there be a lower cost for hardware manufacture and implementation, which requires working very closely with industry. Number three, that there be higher operating reliability and longer life components. Again, some of that is very important for industry and national labs such as Los Alamos and Sandia to work very closely together on. Progress is being made in each of these areas for every one of the technologies which has been discussed already. In addition, new concepts which offer major jumps, rather than evolutionary progress, are also being seen on a systematic basis.

Some of these advances are outlined as follows: I go back to solar thermal again. We are working closely with industry to reduce both the operating and the maintenance cost by the application of improved materials and operating procedures in and of the existing designs. We are working very closely with people in California and other States to see if we can apply some of our additional expertise to cut the operating maintenance costs by 1 to 3 cents per kilowatt hour. That makes a tremendous difference in the selling price of these energies. There are also new technologies such as the dish/sterling engine system, which will have an efficiency in excess of 35 percent. That is 35 percent of the incident sunlight will be converted into electricity. We anticipate a cost of 5 to 8 cents per kilowatt could be generated by the turn of the century. In addition to that, these solar thermal technologies are also being used to consider destruction of toxic chemical waste into very elemental forms. This is another major development effort.

In the context of solar photovoltaics, Sandia is involved in all aspects of research and development needed to make PV an electric utility energy option. At the systems level, Sandia is working with utilities throughout the country to define and field high-energy-value applications. This allows the industry to grow in the utility market while gaining increased utility acceptance. We continue to be involved in defining power system design parameters and array field subsystems, as well as the development of reliable, cost-effective power processing hardware. In the collector, Sandia is pursuing "concentrating" collectors for the utility market. As Mike Davis said, we have seen recent advances where we have had research cells with efficiencies greater than 30 percent, and prototype modules with efficiencies greater than 20 percent. We are supporting the industry in the development and manufacture of low-cost, high-efficiency crystalline silicon solar cells. This is the current mainstay of the photovoltaic industry. All of these technologies are directed towards 12 to 16 cents per kilowatt hour photovoltaic-generated electrical energy in the latter half of this decade.

Now, in the wind technology again, we are still making progress. I mentioned this "natural laminar flow" airfoil technology that had been invented and developed here at Sandia. As you know, we have demonstrated that on a 34-meter wind machine just this side of Amarillo, Texas, in collaboration with the U.S. Department of Agriculture. The very interesting thing is that we find wind industry coming to us to have this technology transferred to them to retrofit many of the wind turbines present in California. We expect that to make a significant positive addition to the cash flow of these wind industry companies. We also anticipate that the new technology demonstrated by the 34-meter device will enable energy costs from wind turbines to be around 5 cents per kilowatt hour once this technology is commercialized and pulled into place.

Geothermal energy, very much like Los Alamos, we are continuing development of advanced drilling, completions, and logging technology which can reduce the costs of acquiring geothermal resources. We also are investigating a concept similar to the hot dry rock activity, and that is looking at drilling into the actual magma of the earth's crust and accumulating energy from that inexhaustible resource.

In summary, Sandia is increasingly optimistic about the value and potential of renewable energy options. Sandia plans to continue its record of leading the development of renewable technologies for both current and future applications of value to the Nation and to New Mexico. We feel that as important as this pursuit will be, it is again the effective alliance with industry and the accurate understandings of the opportunities during the 1990's and into the next century.

Thank you very much.

[The prepared statement of Dr. Dugan follows:]

PREPARED STATEMENT OF DR. VIRGIL L. DUGAN, ACTING VICE PRESIDENT, ENERGY PROGRAMS, SANDIA NATIONAL LABORATORIES

INTRODUCTION

Thank you for inviting Sandia National Laboratories to present our views on the progress which renewable energy has made over the last twenty years and our insights relative to futures for these technologies.

Sandia is dedicated to enhancing the security, prosperity, and well-being of the nation; we work to apply the best integration of scientific and engineering creativity to achieve comprehensive, timely, and cost effective solutions to our nation's most pressing problems. Today's composite of need in energy security and environmental integrity is certainly high on the list of pressing problems. Conventional energy options are faced with serious constraints such as diminishing supply, increasing cost, and environmental effects. Renewable energy options offer premium energy supply futures which are most compatible with environmental preservation objectives and with long term energy security; therefore, they should be viewed as a premium energy supply for the future. For these reasons it is logical and natural that we will see a significant progression of these technologies into both the nation's and the world's energy supply mix over the next few decades.

Recognizing these national needs as well as the potential of renewable energy technologies, Sandia has been actively involved in the development of solar thermal and solar photovoltaic systems, wind energy systems, geothermal technology, and advanced batteries since the early 1970s. Sandia is the site of the Department of Energy's National Solar Thermal Test Facilities, the Photovoltaic Advanced Systems Test Facilities, wind energy research facilities, and geothermal drilling and completions research facilities. Our optimism about the national value of these technologies continues to grow as the world energy and environment situation evolves and as these technologies continue to advance. In my presentation today I will emphasize both the status of some of these developments as well as a vision of future opportunities based on current research and development efforts.

RENEWABLES IN PLACE TODAY

Renewable options are increasingly recognized as the most environmentally compatible alternative energy supply in our national energy mix. Additionally, first and second generation renewable technologies have already become competitive with the costs of some conventional electrical energy supply options.

Significant advances have been made in each of the areas of renewable energy development with which Sandia has been involved, and major commercial installations of the Sandia developed technologies have been realized. As an example, solar thermal-electric technologies developed at Sandia in the 1970s and early 1980s have resulted in several significant commercial power plant installations in Southern California.

Specifically, the construction and continuing operation of the world's largest solar-electric complex of 360 Mwe of hybrid solar thermal natural gas electric power systems was made possible using Sandia developed parabolic trough technology. These hybrid solar/gas systems are capable of selling electricity at 8 to 15 cents/kwh and an 80 Mwe module can be built and placed in operation within approximately nine months.

There are currently about 25 Mwe of solar photovoltaic systems in the U.S. (and perhaps four to five times that amount worldwide) which rely on crystalline silicon cell, module, system, and power conditioning technologies to which Sandia has contributed. These systems are largely used to power remote electrical loads where high reliability in remote environments is critical or where connection to the electric utility is uneconomical. New Mexico, as well, is benefiting greatly from this technology for these types of applications. Photovoltaic modules are very visible as power sources for thousands of applications including highway signs, water pumping and irrigation control systems, bus stop lighting, emergency telephones for highways, railroad crossing signs, rest stop power systems, tourist information radio systems, rural home power and many other users.

Wind energy played a large part in the development of Eastern New Mexico by providing the power source for water pumping and subsequent cattle raising on the Eastern plains. Today's much improved wind energy technology is providing at least 1500 Mwe of electrical power to utility grids in this country as well as continuing to service such needs as water pumping in remote locations. The first generation vertical axis wind turbine technology developed by Sandia, representing 100 Mwe of generating capacity, is providing wind energy at costs less than 10 cents/kwh on sites in both Southern and Northern California.

Sandia has been instrumental in the development of drilling, logging, drilling fluid, and lost circulation technologies for the geothermal industry. The polycrystalline compact drag bit technology developed for geothermal drilling by Sandia is now used worldwide for both geothermal and oil/gas drilling and has an annual value of at least $1 billion. High temperature electronics and other advanced technologies have resulted in sonic televiewers capable of accurately detecting fractures in the severe geothermal reservoirs and new materials have allowed for cost effective control of drilling fluids in highly fractured systems.

A VIEW OF TOMORROW

Continued expansion of the application of renewable energy supply options will depend upon a complex structure of technological, economic, and socio-political advances. A principal need is for society to view renewable energy options which are secure and not environmentally insulting as premium supply options and to grade other supply options relative to this premium. This will require that the full life-cycle cost of capital, fuel production, operating requirements, environmental effects, waste disposal, and system decommissioning be recognized and internalized in the selling price of energy from each option.

The tremendous impact that taxation and regulatory policies have on creating a "level playing field" for renewables cannot be over emphasized. From a technological perspective the keys to success for renewable technologies (1) higher efficiency for collection and conversion,(2) lower costs for hardware manufacture and implementation, and (3) higher operating reliability and longer life components. Progress is being made in each of these areas for every one of the technologies which has been discussed. In addition, new concepts which allow major "jumps" rather than evolutionary progress are also being seen on a systematic basis. Some of these advances are outlined in the following descriptions.

Solar Thermal—Sandia will work with industry to commercialize the new "stretched membrane" collector technology which promises to reduce collector costs by a factor of two compared to the first-generation glass-metal collectors now being used. We are also working closely with industry to reduce operating and maintenance costs by the application of improved materials and operating procedures in many of the existing designs. Major new initiatives involve the development of parabolic dish/sterling engine systems which promise to have solar to electric conversion efficiencies in excess of 35 percent and at a cost of 5 to 8 cents/kwh by the turn of the century. In addition, utilization of concentrated sunlight to destroy toxic chemical wastes is also a major developmental effort.

Solar Photovoltaics—Sandia is involved in all aspects of research and development needed to make PV an electric utility energy option. At the systems level, Sandia is working with utilities throughout the country to define and field high-energy-value applications. This allows the industry to grow in the utility market while gaining increased utility acceptance. We continue to be involved in defining power system design parameters and array field subsystems, as well as the development of reliable, cost-effective power processing hardware. In the collector area, Sandia is pursuing "concentrating" collectors for the utility market. Recent advances include research cells with conversion efficiencies in excess of 30 percent, and prototype modules with efficiencies greater than 20 percent. Sandia also directly supports industry in the development and manufacturing of low-cost, high efficiency crystalline silicon solar cells, the current mainstay of the photovoltaic industry. All of these technologies are directed toward the expected achievement of 12 to 16 cents/kwh photovoltaic-generated electrical energy in the latter half of this decade. In addition to the utility use of PV systems, we are researching methods by which these advanced cells can be used to power the conversion of combinations of carbon dioxide and water directly into stable hydrocarbon fuels—a type of artificial photosynthesis.

Wind—The advanced "natural laminar flow" airfoil technology invented and developed by Sandia has been demonstrated on a 34-meter wide vertical axis wind turbine built in collaboration with the U.S. Department of Agriculture just west of Amarillo, Texas. This new technology allows conversion of wind energy to mechanical/electrical energy with record efficiencies and makes possible the cost-effective utilization of wind technology at moderate to good wind sites such as found in much of Eastern New Mexico and West Texas. We are beginning to work with the wind energy industry in California to bring this technology to the market and expect to see it have major impact on the application of wind machines over much of this country. These machines are expected to produce electrical energy at costs approaching 5 cents/kwh. In parallel with this effort we are continuing to develop advanced materials and analysis tools which allow the design and construction of very reliable, long life wind turbines of all types.

Geothermal—While continuing the development of advanced drilling, completions, and logging technology which can reduce the costs of acquiring geothermal resources, Sandia is investigating an advanced concept for obtaining very high temperature heat from the inexhaustible resources within the earth's magma. This would be done by accurately locating a near-surface magma body, drilling into this chamber, and removing heat by the continuous circulation of a heat transfer fluid. The concept has been demonstrated by successfully drilling into a lava lake in

Hawaii. Current efforts are centered around research at Inyo Domes, California. Future potential locations for this technology include a geothermal site near Socorro, New Mexico.

Advanced Systems Concepts—One advanced concept which is being researched currently is the possibility of using either concentrated solar thermal energy or photovoltaic processes to convert low grade natural gas (contaminated with carbon dioxide and/or water) directly into a high quality liquid fuel such as methanol. This process could have major implications for a state like New Mexico which has large natural gas and solar resource allocations and which requires means for increasing the availability of liquid fuels. Additional system concepts being developed include advanced batteries for electric vehicle applications and high temperature superconducting devices for transmission and compact, high-torque motor/generator requirements.

SUMMARY

We are increasingly optimistic about the value and potential of renewable energy options. Sandia plans to continue its record of leading the development of renewable energy technologies for both current and future applications of value to the nation and to New Mexico. Important to this pursuit will be effective alliances with industry and accurate understandings of the opportunities during the 90s and in the next century.

Senator BINGAMAN. Thank you very much.

Let me ask a little about the role that the labs see themselves here, either one of you. In a couple of these areas it does not seem clear to me exactly what role you see yourself as having over the long term. In the case of improved oil recovery and waste minimization that you and Dr. Whetten spoke about primarily, when you talk about improved oil recovery, it seems to me, not having the technical background in it, a lot of what you are doing there is you are developing new technologies which are useful, and I understand can be commercialized, but you are also providing engineering and technical advice to oil producers who need the technology of how to improve recovery from a particular field. Obviously the lab cannot take on the job of being an engineering consultant to every oil producer that might want to have consultation.

At what stage do you see your role stopping, and you turn your technologies over to some firm that will commercialize that, and turn your knowledge base over to engineering firms that then provide that? In developing technologies and providing engineering advice consultation, where do you draw that line?

Dr. WHETTEN. It is a good question, Senator. In terms of the oil recovery technology partnership, we view ourselves as both a technology provider and as an honest broker in helping provide advice to the companies. In terms of providing the technology, what we are really trying to do is to provide technology which has been developed in areas other than our fossil energy programs to the industry. We are finding that, for example, we have developed technologies for the hot dry rock geothermal program which are directly applicable and appropriate to the needs of the oil industry. The two examples that I cited of doing seismic work and acoustic imaging for the oil industry were spinoffs from the hot dry rock program.

What we are trying to do is work with the industry to test these technologies, to test their applicability in the oil industry. We are very pleased the oil industry then takes the initiative to use these technologies on their own using the advice from Los Alamos.

In terms of waste minimization initiative, what we are attempting to do there is to provide laboratory resources to assist industry in a collaborative effort with industry where industry can really call the shots as to what its problems are, and to see again if we can develop technologies, or if we already have technologies on shelf which can be applicable and used by the appropriate industry.

Sometimes the technologies can be spun off completely to industry. Again I cite the example of the hot dry rock program where we developed an enormous assortment of hardware, logging tools, seals, packers, types of drilling bits in direct collaboration with industry, and many of these devices are now in the catalogs of the service industries, the oil company suppliers, and are using this equipment co-designed by the laboratory in their everyday operations.

Senator BINGAMAN. Let me just press that a little more in the waste minimization area. It strikes me that by far the greatest progress that can be made in the area of waste minimization is essentially in the redesign of products, in the redesign of manufacturing processes to accomplish the waste minimization that you have determined is now a goal of U.S. industry, and that industry has now determined is one of their goals.

Again, are not you essentially providing good engineering advice to them and good design advice to industry, and this is the kind of thing that industrial engineers and manufacturing engineers would be expected to provide themselves if industry told them that in establishing this process or producing this product one of our objectives is to minimize waste? If that was told to a manufacturing engineer or an industrial engineer, presumably they would design that into the product and design that into the process. I am just not sure exactly what peculiar talent the laboratories can bring to that process that a good engineering consulting firm would not.

Dr. DUGAN. I think one way to answer that, Senator, is that very often the engineering consulting firm will do a excellent job of designing a solution or configuring a solution in the context of very well-understood and well-documented technology. They are the best at that.

Very often, though, the national laboratory will come in with something that I would call "new or improved understanding," or perhaps a whole new approach to the process. If I may go back to the oil recovery technology partnership, let me provide two examples. One is that there was a significant problem within the drilling industry of seeing failures of drill pipe which could not be explained. These failures would occur on some completely unanticipated basis, and it would be very costly to the drilling operation to recover from that failure and to restart the drilling. So one of the things that we did in this partnership was to get together with the drilling fluids industry and with the metals industry that provided the drilling pipe, and help to understand what the failure mechanisms were that were causing these problems in the field. Once we had provided that understanding, or helped to configure that understanding, then they have been able to go ahead without these problems.

A second example, one of the industries that we are working with in partnership is Haco in Southeastern New Mexico. They have a very large oil and gas resource base there that is not recoverable with current technology. But some of the technology that has been developed in the context of the U.S. DOE's multi-well experiment in Colorado showed us how to really understand the impact of fractures in naturally occurring reservoirs on production of fluids from those reservoirs. We have been able to take that understanding and translate it to the environment of Southeastern New Mexico and West Texas, and that may be extremely significant. Once we have illustrated to the producer, to the service industry involved in that drilling environment what the production mechanisms are, they go from there, and they design good processes from this.

Dr. **Whetten**. I would only add to Virgil's comment that we see a substantial R&D complement to this program also. We feel in many cases it is going to be necessary to design new materials, which are either less harmful to the environment or cheaper or whatever, to design substitutions for harmful solvents that may be less harmful. We see a substantial area where research and development on the part of the laboratories can be applied to industry's problems.

Senator **Bingaman**. Let me ask one other question. This is to be a devil's advocate a little bit. There is not a lot of love for oil companies these days. People are complaining more and more. How do you respond to a suggestion that taxpayers are supporting the laboratories; and if the laboratories are helping the oil companies to make more money, that should be in some way reimbursed to the laboratories? Some way or another the taxpayers should see some benefit from this process other than just knowing that the world is a better place to live in. For example, when you work with a particular drilling company to improve their ability to extract oil or gas from a particular field, is there any reimbursement to the laboratories?

Dr. **Whetten**. When oil companies or any other private sector firm licenses a technology from a laboratory, there is a royalty agreement whereby that industry repays the Government for the expenses which were incurred in developing the technology. In terms of the activities that we are doing in a cooperative way with industry, this would include the Superconductivity Pilot Center that Senator Domenici referred to earlier, or the oil recovery technology partnership, we find the best framework that seems to work is where the Government pays the share of the laboratory expenses, and industry pays its own expenses. That seems to be a pretty clean way of operating, and it is one that has been very successful for us.

Senator **Bingaman**. Yes, go ahead.

Dr. **Dugan**. If you back up and just look at it from the more national perspective, the intent of the national laboratories is not so much to provide a benefit to the oil industry per se, but to provide a benefit to the Nation in terms of helping to improve the domestic supply base. Today we are producing 7.6 million barrels of oil per day. That is down 1 million barrels of oil per day from last year. That means 1 million barrels of oil per day more in imports. So anything we can do as a Federal Government and as a national laboratory community working with the domestic industry will improve the national position relative to the import dependency and relative to domestic security. So we like to take a more strategic view in that sense.

Dr. **Whetten**. It is a very important point. It is the enhancing of the U.S. production of oil.

Senator **Bingaman**. Senator Domenici.

Senator **Domenici**. Thank you, Senator.

I want to just quickly concentrate in four areas and try to go quick. But let me just start with hot dry rock. Dr. Whetten, let me just say I have been an advocate now at trying to keep your money coming with some success in a little small subcommittee on appropriations for about 6 years. Three years ago we were at a point you were going to get closed down. You came back to life in the last minute. I kind of had to use everything I had in the last minute to get you the final bit of money. I happen to believe in the technology, the new idea as a tremendous source of energy, but I must tell you that you all have to come to a point where you can tell us when it is done or we are going to lose it. We have to have a date. Two more years?

We have to begin to develop some documentation in that regard. This is not said negatively, you know this. But you have made a very, very exciting case for everyone here in this audience, and some may have written about it. Perhaps it is not enough of an issue with all the other exciting things. But what I know is that its support in the committee that does the funding is dwindling because of timetables and failure to achieve certain time-oriented goals. I do not expect you to do that today, other than to kind of give me an idea and give us all an idea where are we?

One other thing that failed a bit was the outside foreign investment. In was not as energetic as it was in the beginning from other countries, and that caused a negative impact on some.

Could you address where are we timewise? How many more years do we fund it in the mode we are funding it? I think it is very exciting. Do not make any negative from me. I think it is important that we know.

Dr. **Whetten**. I appreciate the opportunity in answering that question. First of all, I would say we, indeed, do appreciate not only your interest but your very strong support of the program. It has meant a great deal to us in the past.

I will take the foreign interests first. The Governments of Japan and then West Germany have contributed for 6 years to the program, put a great deal of money in it, and now they are doing their own program.

In terms of the overall time to develop the program, yes, we have been going for 17 years now. That in the perspective of the day-today operation of the laboratory and the Congress may seem like an awful long time. I suspect what you are telling me is that, in fact, it is. However, it is very difficult to develop, and I would, I guess, challenge anybody to give me a comparison where a new energy source has been developed in a period of time much less than 20 years. This is going from concept, to proof of feasibility, to the engineering feasibility, and so forth. We think we are very far along on that track, and, in fact, we see that the particular program at Fenton Hill does have an end, and the end that we are striving for is to get the engineering parameters to convince industry to invest its dollars in the perpetuation of this technology.

What we would like to do, and we have gotten the advice from industry that this is what we, in fact, need to do is to run a the test of that system for approximately 1 year. And we have been trying to gather the resources for the last 2 years to do that remaining 1-year flow test. We appreciate your help in doing that.

In actual dollars what has been appropriated now for fiscal year 1991 is $3.6 million. We need an additional $4 million in order to do that test, and we had hoped to start that test in fiscal year 1991. My guess is we are now deferred to the fiscal year 1992 until we can accumulate the resources to do it.

Senator DOMENICI. Let me say that both of you have commented on the energy development partnership that former Secretary Wapler started, predecessor to our guest who spoke first. First, I want to say to both laboratories, I am very, very complimentary of this program and very excited about it. There are some who might be worried about the Chevrons and the Exxons, but the truth of the matter is this is the first program that has excited independent petroleum and gas producers in the State of New Mexico. They are the ones that came to the meetings. They were the ones that told us they needed help. They are the ones we are trying to help; and from what I can tell, they are the ones deriving some very exciting new ideas about improving their businesses and ability to recover in more economic ways, and some even have developed some computer and other technology for the independent oil and gas industry from what I understand. Am I correct in that regard?

Dr. DUGAN. Yes. There have been numerous cases where the contributions have not been global in a sense, but there have been small things. Just to get a computer code or an understanding of how to run a computer code to participants within this partnership. We do not sometimes highlight those as much as others, but to the operating company they can be extremely important, and that has occurred by contacting both Los Alamos and Sandia.

Dr. WHETTEN. We have been gratified by their response to our efforts. They have told us, and I think they have been willing to go to Washington and inform the department and you people of their satisfaction. That, of course, pleases us enormously.

Senator DOMENICI. Let me talk about transportation, automobiles, for 1 minute and one aspect of it. I guess there are two things that are about as American as you can make them; one is to own your own house, and the other is to own your own car. I do not think we are going to change that. For those who are worried about energy problems, I surmise that we are going to find the way to give Americans the ability to drive around in a car before we convince them that that life style ought to disappear.

So I think one of the most challenging things of all has to do with how are we going to do that? I want to talk about batteries for a minute, because I have heard so much about it for so long, and one of my best friends in the Senate, Senator McClure, has already made a career and left, just decided he is not going to be a senator any more. He was going to be there to see battery-driven cars all over the United States.

I am told that Thomas Edison said, "Show me somebody who says he has a better battery and I will show you a liar." That is a long, long time ago. The kind of battery that he was talking about is the alkaline battery and it is still the battery.

Could you just quickly tell us, if it is in your field, where are we going in this area? Are there some breakthroughs? Are we just sputtering around making some kind of marginal advances, and will we be in that mode for a substantial period of time?

Dr. **Dugan**. If I may speak to that, I would hesitate to disagree with Thomas Edison.

Senator **Domenici**. Oh, you can. He did not know about computers so that changes everything.

Dr. **Dugan**. But there are some significant advances being made in battery technology. We are very accustomed, of course, to the lead acid battery that we have in our automobiles today. Interestingly enough, there are even some advances in advanced lead acid batteries that keep the battery plates from shedding the oxide and shorting out the cells and therefore being dysfunctional in a fairly short number of years. Those battery technologies are present today and could be put into automobiles today. They have not been because of the cost considerations of low-cost batteries that go into automobiles today. But we are seeing very great interest in advanced lead acid batteries.

As far as completely new technologies are concerned for automobiles, the sodium sulfur battery is one that has been worked on for a long time, and again is receiving significant interest from the automotive companies that Mike Davis referred to. There have been a lot of problems in seals. Now, these are not seals as in the petroleum industry, but glass, metal seals or ceramic seals that have to be kept intact on these batteries. I think that technology has come to a point in maturity now so that safe, reliable and very high-powered density, high-energy density batteries are just on the verge of being commercially attractive.

There are some very reliable batteries that are today present. A number of companies are building batteries for space applications that are aluminum air, zinc air, batteries of this sort, that are very reliable and can be abused in any sense but they are very costly. The reason that they are costly is because, again, they have not been engineered for the commercial transportation applications, and they have not been produced in volumes that allow the discount that volumes give.

All of these things, though, are coming to the forefront. I think we will see a revolution in battery technology in transportation applications within the next 10 years.

Senator **Domenici**. Thank you very much.

You really believe that? You believe we should keep pressure on then in terms of forcing the automobile manufacturers to have certain various rations in terms of the automobile fleets in certain cities that are highly polluted? And looking to new technology, this may be one of them that they would be pushed to.

Dr. **Dugan**. Rather that forcing, I would say things like the Clean Air Act.

Senator DOMENICI. That is what I mean. That is what it does. It says in the 20 or 30 cities there is going to be a different mix of automobiles. That is not necessarily forcing them. If they do not, they do not sell cars.

Dr. DUGAN. That would seem to me to be very adequate to stimulate a unsurmountable electric vehicle production. Again, if you think about electric vehicles, then you can think about renewable energy supply sources within the electric utility sector supplying the energy for those batteries, which is an offset against the oil that we are so concerned about. I think that is a key strategic direction.

Senator DOMENICI. With reference to your environmentally conscious manufacturing joint efforts between the two labs and others—I guess that is what I called it. You called it waste minimization.

Dr. WHETTEN. Waste minimization.

Senator DOMENICI. So I am talking about the same thing, environmentally conscious manufacturing. Somebody called it that. Sort of sounds nice to me. Let me ask, is there real energy savings involved in the potential here? And as I understand it, the Department of Energy is looking at our laboratories as maybe a principal place to start this moving. Could you just quickly tell me how much of this is energy, and how much of it can be in any way related to defense activities? The latter is because of funding which concerns me.

Dr. DUGAN. I think it is both, Senator. The nuclear weapons complex is certainly one opportune location for the implementation of some of these advanced manufacturing concepts. As John Whetten said, almost everything we do is related to the energy, environment, and economic competitiveness, and you have to fold these three together to really have a good solution. You do not want to have an objective that is based upon only one of those. You want to have an objective based on all three of those as a composite.

Some of the manufacturing, advanced manufacturing technologies, involve things like using substitute fluids or substitute machine practices that are not as environmentally insulting as maybe the conventional ones. Using advanced technologies like some of the intelligent machines that allow things to be done more quickly and without as much human exposure is perhaps some of the——

Senator DOMENICI. Let me just say I understand that. Let me just ask a very simple question. Could some of the activities in the manufacturing field be in some way related to the defense industry of the United States?

Dr. WHETTEN. Indeed it could. I think the substantial amount could.

Dr. DUGAN. Yes.

Senator DOMENICI. Are any of those companies that are going to be involved defense industries, and if the chairman does not mind, could you supply us with some indication of what defense industries might be affected by environmentally conscious manufacturing?

Dr. WHETTEN. We have defense industries that have indicated an interest, and we would be able to supply you with those, names of those firms.

Senator BINGAMAN. Thank you both very much. I think we probably need to move to our third panel. We appreciate very much your testimony.

The final panel has several people on it. Dr. Barry Butler, who is Chairman of the Solar Thermal Power Division, Solar Energy Industries Association. We have James Hanson, President of the National Geothermal Association. Jan Hartke, who is well known to all of us here, and is a member of the Board of Directors of the Global Tomorrow Coalition. He is accompanied by Roy McAlister, who is President of the American Hydrogen Association. Colleen Fordyce and Heidi Harris are here representing the Students for Environmental Education at Highland High School.

We will hear first from Colleen Fordyce and Heidi Harris about their activities and their views at Highland High School.

Can you maybe pull that microphone over to whichever one of you wants to speak first. We will hear from you and then hear from the other panelists, and then we will have questions of all of you.

STATEMENT OF COLLEEN FORDYCE AND HEIDI HARRIS, STUDENTS FOR ENVIRONMENTAL EDUCATION, HIGHLAND HIGH SCHOOL

Ms. FORDYCE. It is time for America to stop making do—time to stop accepting what we know can be improved. As Americans we have always prided ourselves on our innovative and bold steps towards the future; now more than ever we must live up to that tradition. There are many factors which determine how successful we are as a member of the world community: education, industry, leadership, and quality of life are all important. However, how great can we be without a force to power our lives? Americans must understand that we can no longer depend solely on fossil fuels. How can we sit back and watch ourselves and our neighbors blindly sacrifice the future of our children by refusing to recognize innovative energy possibilities. We must acknowledge how very limited our supply of fossil fuels is.

Ms. HARRIS. How many people realize that in the next half century all of the current sources of coal and oil will be exhausted? Once the convenient sources are depleted, we will be forced to seek alternative methods of obtaining these precious materials, the life blood of our society. We may look to extracting oil from shale—a process which is more expensive, more sophisticated, and less productive than any type of widespread oil production today.

Ms. FORDYCE. Our world is particularly a unique planet. Earth is rich in plants, animals and minerals—a planet literally packed with energy potentials. Thankfully, fossil fuels are not our only means of producing power. The new alternatives, which science has given us, must be explored and implemented. Possible energy supplies range from solar power to harnessing the wind's invisible force. Even the oceans provide potential energy resources.

Ms. HARRIS. Using salt water from the oceans, it is possible to produce hydrogen through a process called electrolysis. Hydrogen can be used to power different types of transportation, along with other devices. It is clean burning, and better still has only one biproduct, water. The oceans can produce more than just one type of potential energy. Using the tides you can generate electricity. The process uses the waves' constant motion to spin a turbine. This same principle may be applied on land by using dams and water wheels to create a similar force. Our seas are not alone in their capacity to produce energy. Earth's land masses also provide numerous sources of energy.

Ms. **FORDYCE**. Beneath earth's crust is a vast reservoir of geothermal heat. When water is added, either through man's action or nature's, steam is produced. The steam can then be utilized to generate electricity. Geothermal heat is already being used in a variety of areas and is a very effective means of energy production.

Ms. **HARRIS**. Another major contributor is man himself. Using a process called bioconversion, it is possible to convert plant and animal waste into methanol, oil, and natural gas. In fact, the waste-processing plant in Albuquerque uses the methanol produced from sewage treatment to power all of its vehicles.

Ms. **FORDYCE**. It is possible to obtain energy from countless other resources. Most of them, and certainly the most economical of these new resources, are renewable, a great advantage in today's energy hungry society. Renewable energy sources rarely harm the environment, and most often work to preserve and protect it instead. All you have to do is apply a little imagination and look for the possibilities. There is always an answer.

Ms. **HARRIS**. New energy policies are a must if we are to continue as a leading member of the world community. Although experimentation and testing of the new energy supplies will be expensive, in comparison to the total cost of developing them after the need has arisen, the price today is infinitesimally small. We urge you to consider this as you decide the future of our nation's energy policies. It is essential that these decisions reflect not only imagination and innovation, but also respect the environment. Any choices you make must be a balance between social, economic, and environmental needs. Cooperation and compromise are necessary if we are to succeed—if the future is to succeed. Throughout history humankind has repeatedly taken not only from earth, but from each other. Now we must change this destructive cycle and begin to give back what we consume. The first step starts here with you, and us, making a commitment to work together fulfilling the future's potential, as a race in love with each other and a world in harmony with her children.

Ms. Fordyce. Thank you for allowing us to actively participate in our future.

Senator **BINGAMAN**. Thank you very much. It is an excellent statement. There are some very good thoughts in there, and we will pursue with you some questions.

Why don't we go and hear from the other witnesses first, and then we will have some questions of the whole panel.

Dr. Barry Butler, as I indicated earlier, is Chairman of the Solar Thermal Power Division of the Solar Energy Industries Association. Why don't you go ahead, Dr. Butler?

STATEMENT OF DR. BARRY L. BUTLER, CHAIRMAN, SOLAR THERMAL POWER DIVISION, SOLAR ENERGY INDUSTRIES ASSOCIATION

Dr. **Butler**. Thank you, Senator. It is a pleasure to be here to represent the industry. To give you an idea of what that industry is we have 15 PV manufacturers that sell $175 million of product a year. Thirty-five solar thermal manufacturers that are selling about $200 million worth of product, and the solar building industry which sells $400 million worth of product. Our industry today represents about $775 million and employs 25,000 citizens of this country making energy for citizens of this country.

We recognize in the industry that the labs can develop technology, but only politics will determine how it is used. The potential of the atomic bomb was developed at the laboratories, but only the political environment could determine how it was to be used. Our industry sees it the same way. We see the laboratories as a resource. Los Alamos, Sandia, and SERI all represent national lab resources that this community can draw heavily on.

Our industry association is a little less timid than Mike Davis. We believe that you will never go anyplace unless you have a goal. Our goal has to be concrete, and it has to be something we can achieve. We, as a industry association, put forward the goal of energy independence by the year 2020. When we say "energy independence," I think what we are really talking about is lowering our energy dependence to a level we are comfortable. We are not saying we should isolate ourselves in the world, but we should become comfortable with less so we do not have to get it elsewhere.

The recent lessons have taught us that without a goal and without progressing toward it that the old saying you pay me now or you pay me later comes into play. Certainly we have low energy prices, and we are all very happy about how we could develop that into the infrastructure. But now, if you will look at what it has done to the stock market, and your pension plan, if you go to look at what happened to it in the future, we are going to pay the price, whatever it really is. We need to get the energy balance right in this country.

So we recommend the goal of energy independence by the year 2020. So what we said then is, you just take 2020 and put a slash in the middle, we have had fuzzy vision on energy policy and we need 20/20 vision on energy. We need a policy that focuses on energy, and we would ask the Congress and the administration to take the lead.

Everyone is going to have to participate to achieve energy efficiency, change the energy use habits, incorporate the technologies, and alter our lives. But that is the history of the country so that there is nothing new in that. What we need the Government to do, and we provide several specific items, but the first thing we need to do is we need the Government to make sure that we are sending the correct signal. People respond to a signal. And as you have heard in the previous testimony, the energy cost must bear all of the costs; not just the cost of pumping it out of the ground and delivering it to a station. It has to include the cost to the environment, the energy security of the country, the job security, and the disposal costs.

We see in the renewables industry that if you put those costs into all the systems, then consumers will make the right choices. They will buy the systems and implement the technology that will save the energy. Why do we in solar renewables feel that we will be chosen? I am not saying that we are against nuclear power or any other source of power, all we want is to have a chance to be chosen with the right factors involved. So renewables have no environmental impact. We know that. Solar supply comes without geopolitical influence. We should not have wars over solar if we can generate enough power.

Solar creates taxpaying industry and jobs in this country. We want Americans building energy systems for America. We are letting our foreign competition run off with our products and selling them back to us. We will import energy technology if we do not beef up our R&D and keep our industry ahead of the world. These jobs pay taxes, and they build the infrastructure. If we put together an enhanced scenario, this industry could employ 2.5 million people before the year 2020, significant industry. Much of that will be developing in the Southwest. If you look at the geo-influence of our companies, the Sunbelt is where the action is.

Solar waste products are similar to other U.S. industries. We have industrial wastes in building photovoltaic modules and making solar thermal power systems, but they are not especially toxic or hard to deal with. We need to deal with that overall.

We, as an industry, feel that we can provide by the year 2000 8.75 quads, or almost 10 percent of the energy that this country uses. That means we have to do a lot between now and then. I am not unwilling to make a statement about what I think the DOE budget ought to be. I worked at Sandia for 10 years, and SERI for 7 years, and I know the Government process and I know the good value that the citizens of this country get for those dollars.

In 1981 we had $800 million going into solar renewable research, and the progress was vigorous and the goal was clear. President Carter stated it; he had stated energy independence, and we are following that path. It might have been too aggressive, perhaps, but during the Reagan administration, now that Bush administration, the budget has shrunk to less than $100 million, and this year's proposal to raise it by $27 million, so it is $127 million, just, in our opinion, is not enough to get the job done. It is not enough to forge that partnership and reduce the risk to make these technologies move rapidly. We believe the DOE ought to add $500 million a year for the next 10 years; and then if you provide it, they will manage it well, and you will get a return on investment for the country that is worth it.

The question was asked earlier about the national labs helping specific interests. The answer is in many cases the people that come to take the technology do benefit directly, but by benefiting we create jobs, tax revenues, and a sustainable energy future that will not take away from our children, and will give to the future a sustainable energy system.

I think that our industry supported the nomination of Mike Davis as the deputy assistant secretary, because he is the guy that can get the job done. But without the goal of 20/20 energy vision, we are not going to get anywhere, because we do not know where we are going. Mike is going to provide a framework, but we have to have legislation and pressure that will force the administration to provide a goal because otherwise we are just going to wander around.

I have 10 specific recommendations which I wrote into the testimony. I think in order to leave some time for the other speakers, I will not go through those in detail. But the President can set the goal. We think that needs to be done. There are several policy issues related to utilities and what I call making the decisions, the right ones, sending the right signal. Purpose is clearly one of those. The Sharp/Baylor legislation is going to help us move these technologies forward.

Giving utilities low-interest loans so that they can buy the more expensive up front cost of solar technology for the lower long-term cost of solar technology is an approach that needs to be looked at.

Tax incentives based on clean energy production or tax incentives for not producing acid rain, so production credits for clean energy basically.

A 10-percent tax credit for energy development was enacted for 1 more year. We believe it needs to be in place 5 or 6 more years. How can industry build a plant that is going to bring 300 megawatts on line not knowing whether they will be able to qualify for a tax credit a year hence? If they do not get it on line a week ahead of time and get the turbine rolling, they could lose their entire system, lose the tax credit which would really damage their ability to formulate capital and make the investment.

I have already talked about PURPA. We believe that we should actively develop an export position for our technology. We should not give it away, and then buy it back. We have done it with other technologies. And so thermal technology we are still in the lead, but I am very disappointed to report that photovoltaic technology. We used to sell 70 percent of the world's photovoltaics; now we sell less than half. With the Japanese going the way they are going, it looks like a third. They are doing exactly the same thing with solar thermal technology. The rest of the world looked at what we have done, and now are looking at taking it away. We are now selling more solar thermal technology than anyone else in the world, but it is just barely above 50 percent. If we continue to allow our posture to erode, we will be buying that technology back.

We have provided DOE with initiatives. Mike talked about the photovoltaics. There is a thing called the solar thermal electric power initiative. There is also a solar detox initiative. DOE is responding to industry's requirements and is working with industry on those initiatives.

So I will end with my initial statement; it is time that we have 20/20 energy vision, and that I think our industry wants 20/20 solar energy vision. We want that in the context of an overall process, and we believe we can deliver significant energy to our society and create jobs in a healthy environment.

Thank you.

[The prepared statement of Dr. Butler follows:]

PREPARED STATEMENT OF DR. BARRY L. BUTLER, CHAIRMAN, SOLAR THERMAL POWER DIVISION, SOLAR ENERGY INDUSTRIES ASSOCIATION

INTRODUCTION

The Solar Energy Industries Association feels that in order to make progress we must have a goal:

> Energy Independence for the USA by the year 2020.

With congress and the administration setting the goal, who will help to make this a reality?

> Everyone must achieve energy efficiency improvement, change energy use habits, and incorporate solar and renewable energy technologies into their lives.

With the goal and the desire to make energy independence a reality, what do we need to do?

> Government must send the correct singal. Energy cost to the user must include environmental cost, energy security cost, job security cost, and disposal cost.
>
> Consumers and energy producers must weigh the costs and choose from the options based on all of the costs.

Why do solar and renewables feel that they will be chosen when all costs are considered?

1. Solar and renewables have minimal environmental impact and cost.
2. The solar energy supply comes without geopolitical influence, no solar wars.
3. Solar creates tax paying industry and jobs in the US, building energy plants for US citizens.
4. Solar waste products are similar to other US industries.

CONSIDERATIONS

In June 1989, the U.S. Environmental Protection Agency and the U.S. Export Council for Renewable Energy (a coalition of the nine national renewable energy trade associations formed to promote exports of alcohol fuels, geothermal, hydropower, passive solar, photovoltaics, solar thermal, wind and wood energy) hosted a Forum on Renewable Energy and Climate Change. The leaders of this nation's private sector renewable energy companies gathered in Washington. D.C. to advise EPA on the potential "real world" contributions our industries could make in a business-as-usual scenario or an enhanced scenario. My presentation on behalf of the SEIA manufacturers, project developers and component suppliers in both the solar thermal and photovoltaics industries. Under enhanced conditions, active solar water heating, photovoltaics, and solar thermal utility-scale plants could meet 8.75 quads by the year 2000, approximately 10 percent of USA projected energy consumption. In a business-as-usual scenario, out industries will barely make 2.1 quads by the year 2000.

The United States policy regarding solar and renewable energy over the last decade can be best characterized as "benign neglect". DOE funding went from $800M/year in 1981 to less than $100M in 1989 causing a void in development. Our international competitors aggressively stepped in to such an extent that the United States may import all of its solar energy technologies by the year 2000 and lose our world markets as well.

Why would the United States, after inventing and holding the technological lead in all solar technologies, allow our competitors to commercialize our inventions and reap the hundreds of millions of dollars in taxable profits and thousands of jobs in solar energy?

While the Carter Administration policies may have caused over expectation in what solar energy can accomplish, the Reagan Administration discounted any contribution, even though our aggregate sales for solar systems and components approach $1 billion per year. While the rhetoric from the Bush Administration has been more favorable, our industry is concerned that fine rhetoric and "no goal" can have the same sad result; the United States continues to lose domestic and world market share and the action shifts to our international competitors.

The President should be commended for nominating the first Assistant Secretary for Conservation and Renewable Energy of the U.S. Department of Energy in history, with not only the appropriate technical credentials, but with actual private sector experience in both energy conservation and solar energy. Yet without the Energy Independence goal by 2020 set by the President and the Secretary of Energy, Mr. J. Michael Davis will be unable to positively effect a U.S. energy policy which is still fixated on conventional energy and not technologies that will maintain U.S. energy security and leadership in the twenty-first century. The "20/20 Solar Energy Vision" is needed to promote all energy systems including solar and renewables.

Briefly, I will advise the U.S. Senate Committee on the programs and policies necessary to promote solar and renewable energy applications over the next two years. However, it is sad that the Environmental Protection Agency took the initiative in gathering the U.S. renewable energy industry together to assess our potential, rather than the U.S. Department of Energy. With increased oil imports, increased environmental degradation, and increased usurpation of the solar industry in international markets, it is time for the Department of Energy and the Administration to reassert themselves in energy policy and take some proactive steps to build a viable and growing U.S. solar energy industry by setting the goal of "Energy Independence by 2020."

TEN U.S. POLICY OPTIONS TO BUILD A U.S. SOLAR INDUSTRY

Half of these options will not increase the federal deficit in any way, and the other five options, in aggregate, will not surpass federal support for the conventional energy industries, i.e., oil, gas, coal or nuclear.

1. Use of the "bully pulpit" of the Presidency to state the goal of "Energy Independence 2020" to promote solar energy—both the President and the Secretary of Energy, through speeches and site visits, can encourage government, commercial and residential consumers to utilize solar energy which will build confidence in the consumer and investment communities. The President should have 20/20 energy vision. Increase in federal spending: $0.

2. Allow solar-electric applications to be used in situations where the Clean Air Act limits new electric production—Why shouldn't a utility be able to build solar energy plants which have no emissions? Increase in federal spending: $0.

3. Incorporate regulations for easier loans/mortgages from FHA/VA/FmHA when solar energy applications (passive solar, photovoltaics, and solar thermal) are installed in the building—Use of solar appliances which lowers energy bills allowing owners to have more expendable income and thus more easily afford the mortgage/loan. Increase in federal spending: $0.

4. Solar energy research and development must be maintained by the United States—Solar energy R&D in, photovoltaics, solar thermal, solar buildings, wind, and biomass must be enhanced to $500 million/year to ensure that technology developed in the 1980's actually reaches the marketplace. Increase in federal spending: $363 million/year.

5. Taxes on electric production to offset acid rain should have set-asides for solar and renewable energy—Proposals to tax fossil fuels use in electric production should include a 15 percent set-aside for utility incentives to build solar and renewable energy plants which would directly offset coal burning. Increase in federal spending: $0. (New fee, off budget).

6. Continue the 10 percent solar energy business tax credits which are due to expire on December 31—This small incentive decreases the risk for commercial customers of solar energy. The tax credit has been essential for the private sector to install 350 megawatts of utility-scale power, and if passed will attract capital for another 400 megawatts in 1991 and beyond. Increase in federal spending: $25.0 million/year.

7. Require passive and active solar applications in all new federal buildings and create incentives for third-party financing of solar process heat and solar-electric plants—The federal government is the largest energy user and largest building builder and owner in the United States. Increase in federal speeding: $0 (Energy savings alone will make up for increased outlays for solar equipment, materials, or tax preference for third party investors).

8. Lower cost of capital for utilities and private companies to build utility-interconnected solar plants and load reducing solar systems by providing a subsidized loan program to lower front-end capital costs—Such bold action will allow utilities to justify new plants and load reducing solar system before State Utility Commissions and to their investors. A similar program should be developed for residential consumers using the oil overcharge and stripper well funds distributed to state governments. Increased federal spending: $50 million per year for ten years for utility

applications. $0 for residential since these are now counted as off-budget expenditures.

9. Allow federal-set-asides for solar and renewable energy electric power plants less than 500 megawatts under the Public Utility Regulatory Policies Act (PURPA)—By allowing solar plants a waiver from bidding and increased regulatory costs, use of solar plants for peak power will become the energy of choice. Increase in federal spending: $0.

10. Provide export set-asides for solar equipment through the Export-Import Bank, Overseas Private Investment Corporation, Trade & Development Program, as well as the World Bank and the three regional development banks—Currently, these institutions invest most of their energy money for diesel and coal use in the Third World, making them more reliant on energy imports and less able to pay their debts. Increase in federal spending $0.

Most of these suggestions need no Congressional action, just action by the Executive Branch. In total, for $438 million per year, the United States could have a thriving solar industry providing more than eight quads by the year 2000 and with export sales over $2.5 billion.

CONCLUSION

The administration and congress must get "20/20 Solar Energy Vision" and set the goal of "Energy Independence by 2020."

The administration and congress must send energy users the correct signal. The administration's recommendation to increase the DOE solar budget from $98M to $127M is inadequate, to assure energy independence $500M/year will be needed. The House Ways & Means Committee's must extend the commercial solar tax credits for solar industrial process heat and solar electricity at 10 percent or greater for the next 10 years.

In order for the U.S. solar energy industry to increase world market share, the industry must increase the domestic market. Low cost incentives promoting residential and commercial use of solar energy, federal procurement, and utility-scale generation are necessary. New incentives would not cost more than $438 million per year and many would save consumers and the federal government millions within a decade. The incentives will also create revenue from income taxes on solar industry employees and corporate taxes.

Aggressive use of solar applications to offset pollution is essential. Incentives which lower the risk and increase practical applications make the most sense. While the United States has one million solar water heaters, the City of Tokyo alone has an equal number. Our international competitors understand the need to implement policies to build domestic markets and cut oil imports. Why can't the United States understand this need? If the United States is not vigilant, not only will our petroleum imports surpass 50 percent in the 1990's but our solar imports may surpass 50 percent by the year 2000 from the very countries we import cars and VCRs. Such an outcome would be a tragedy.

"20/20 Solar Vision" will be needed to achieve "Energy Independence" and lead the solar and renewables movement world wide. We can develop, use and export the energy independence movement and products to the world.

Senator **BINGAMAN**. Thank you very much.

Let me call on our remaining witnesses here. Let me urge that people try to summarize as much as possible so we will have time for questions also.

Next is James Hanson, President of the National Geothermal Association. Why don't you go right ahead. Thank you for being here.

STATEMENT OF JAMES HANSON, PRESIDENT, NATIONAL GEOTHERMAL ASSOCIATION, ACCOMPANIED BY DAVID N. ANDERSON, EXECUTIVE DIRECTOR, NATIONAL GEOTHERMAL ASSOCIATION

Mr. **HANSON**. Thank you, Senator Bingaman, Senator Domenici, staff members, ladies and gentlemen.

As you said, my name is Jim Hanson. I am President of National Geothermal Association, also an employee of A-Z/Grant International, a company that has been involved in geothermal industry since 1969. We are also involved——

Senator **Bingaman**. Would you pull that microphone up a little closer there, please? Thank you.

Mr. **Hanson**. We have also been involved in the Department of Energy through the geothermal drilling organization in conjunction with working with special high-temperature elastomers through the labs, Sandia and Los Alamos. The project is in conjunction and is a cost-sharing project.

I am speaking today on behalf of the three groups, the National Geothermal Association, the Geothermal Resource Association, and the Earth Energy Association. We are industry associations of 70-member companies and utilities who are concerned with the development of geothermal resources, both in United States and abroad. I very much appreciate the opportunity to address this joint field hearing.

I am here to suggest that Congress can help supply the energy needs of the United States, while improving the world environment through action in four areas. First, support of tax and regulatory treatment that promotes the development and the use of geothermal energy. Second, a strong geothermal R&D program and recognition for geothermal energy in the National Energy Strategy. Third, assistance in generating exports in the rapidly growing foreign geothermal market. Fourth, Federal leadership in implementing the use of geothermal energy in the United States.

Before I discuss these four matters in more detail, I would like to make a few remarks about the nature of geothermal energy and the advantages of its use.

Geothermal is heat from the earth. It is earth energy that can be used to supply heat for generation of electricity and the direct use to such industrial processes as district heating and hot water. It can also be used to reduce the demand for electricity and natural gas through geothermal heat pumps. In other words, geothermal energy is important both from a new energy supply and in reducing energy demand.

Geothermal energy is environmentally advantageous. The release of greenhouse gases and acid rain gases from geothermal generating plants is minute, very much less than the release of these gases by coal-, oil- or natural-gas-fired power plants. Coal-fired generating plants release 1600 times more carbon dioxide than a geothermal plant for each megawatt of electricity produced.

Geothermal plants have a small footprint. They take up only small amounts of land. Other land uses can mingle with the geothermal use with little interference.

Best of all, geothermal energy is here today. It is not just a hope for the future. Five thousand seven hundred megawatts of geothermal electricity are on line worldwide. Here in the United States we have 2,800 megawatts of capacity at an approximate cost of 4 to 6 cents a kilowatt.

There are thousands more thermal megawatts being produced for direct application worldwide. Moreover, geothermal heat pumps are operating throughout the world. There are over 100,000 in the U.S. alone. They are important contributors in saving hundreds of megawatts of electrical demand in the United States. If oil were burned to supply the energy that geothermal heat supplies today in the world, more than 150 million barrels per year would be required. One hundred fifty million barrels per year is enough oil to completely refill our Strategic Petroleum Reserve every 4 years.

Nevertheless, much more geothermal power could be developed, better technology with proper incentives. The geothermal industry needs and wants support from the Federal Government. We are asking for support in four areas. We need a fair tax and regulatory treatment that will stimulate development of sustainable and environmentally advantageous energy sources. Tax credits should be allowed for the installation of geothermal energy. The geothermal tax credit, which expired in September and which has been renewed for 1 year, should be made permanent. Other tax incentives similar to those that exist for development of oil and gas should also be made available to geothermal development as well.

We also strongly support the legislation that was introduced by Senator Domenici that removed a load of 80 megawatts for PURPA power plants. We thank the senator for his support of this issue. Additionally, we would like to see geothermal energy removed from the optimum penalty tax.

Second, the geothermal industry needs the support of a strong Federal Government R&D effort. Better technologies are needed to take advantage of the full range of geothermal resources. Geothermal research budget for the Department of Energy was slashed by a factor of 10 over the last decade. As a result, we missed a honeymoon period of cheap energy, a gift of time when we should have been developing and implementing technology for a more energy-efficient economy.

Now that the oil prices have gone up, we strongly urge Federal action and leadership. We recommend the Department of Energy be encouraged to include an aggressive R&D program in the geothermal energy National Energy Strategy in the budget request. Most importantly, we request that Congress fund a strong geothermal R&D program. The fiscal year 1991 geothermal budget request by our administration was much too small at $18 million. We note with gratitude that Congress increased this amount to $27.6 million. We recommend a minimum amount of $35 million for fiscal year 1992. This amount was suggested in 1987 by the National Academy of Sciences to study geothermal R&D needs in the United States.

We also note that the geothermal program pays for itself. There is over $20 million a year taken in by the Federal Government from royalties on geothermal properties produced on Federal lands.

Third, we need assistance from the Federal Government to penetrate the rapidly developing foreign geothermal market. Countries, such as Japan, offer of tied aid and low-cost loans to third world countries in return for use of their business services on energy products. The subsidized financing that our foreign competitors are able to offer knocks U.S., or knocks us, out of the competition. We believe Congress should rectify this situation. We endorse S. 2703, which would tie a portion of U.S. AID funds to the purchase of U.S. goods and services.

Fourth, we strongly recommend that the Federal Government take the lead in promoting the use of sustainable energy resources.

Several things are needed. It goes without saying that a solid national energy policy is mandatory. We believe that the Government should set an example in the promotion and use of sustainable energy such as geothermal. In recent years the geothermal option has been largely dropped from the utility agendas. This is difficult to understand in view of the increasing degree of power-system interconnection. The whole country would benefit from geothermal power development anywhere within its borders.

Geothermal industry needs help in institutionalizing geothermal among energy sources. We need recognition with the top management of the Department of Energy of our viability and potential for a significant power source.

On the issue of setting an example, we recommend and encourage development of hydrothermal resources on BLM, forest service and Defense Department land. We also recommend that efficient geothermal energy be used in Federal buildings, installations, and Federal housing projects. Converting to the use of geothermal heat pumps would save the Government cost of electricity and gas costs.

In summary, we believe that the geothermal energy can contribute significantly to decrease our dependence on foreign energy source while helping to preserve the environment. This, Senator, is a home run that we want to hit. We do not want to strike out. In order to be effective, we need tax and regulatory treatment that will help nourish our industry, a strong Federal R&D support, a system of competing with several foreign nations for the large geothermal market, and leadership in implementing the use of geothermal energy. The National Geothermal Association has worked and is working in providing a renewable energy for commerce and trade with great success.

I thank you very much for this opportunity to give my views. I hope I did not take too long in my report.

[The prepared statement of Mr. Hanson follows:]

GEOTHERMAL ENERGY IN THE UNITED STATES

prepared for the

JOINT FIELD HEARING

of the

ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
and the
MINERAL RESOURCES DEVELOPMENT AND PRODUCTION SUBCOMMITTEE

of the

SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

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1 November 1990

CONCLUSIONS

Geothermal energy, heat from the earth, is a domestic resource that contributes to our energy security and decreases our trade deficit by displacing imported fuels. It is an environmentally advantageous energy source that produces far less air pollution than fossil-fuel sources. Geothermal energy contributes both on the ***energy supply side***, with electrical power generation and direct-heat applications, and on the ***energy demand side***, with savings in electricity and natural gas through use of geothermal heat pumps in buildings and industry.

Only a small fraction of our geothermal reserves are in use today, but much more could be brought on line in the short term with appropriate incentives and aggressive R&D. The National Geothermal Association, the Geothermal Resources Association and the Earth Energy Association strongly urge the Congress of the United States to:

1. Enact tax and regulatory legislation that encourages the development of domestic geothermal energy supplies;

2. Appropriate sufficient research funds to ensure that the diverse potentials of geothermal energy are realized both in the United States and in the rest of the world;

3. Devise and adopt strategies that will enable the U. S. geothermal industry to compete fairly with other countries that export geothermal goods and technology for the large foreign geothermal market in the third-world; and,

4. Take a leadership role in encouraging the use of sustainable energies through embracing a thoughtful national energy policy, helping us to institutionalize geothermal among energy choices, encouraging the development of geothermal resources on Federal lands and setting an example by converting to geothermal energy use in Federal buildings, Federal installations and public housing projects.

NEED FOR AN EFFECTIVE ENERGY POLICY IN THE U. S.

The United States and other developed countries have energy-based economies. Our manufacturing, mining, agricultural, fishing and transportation sectors all rely on abundant energy, while home energy use is the basis for our comfortable life style. Our well being and comfort depend on the availability of a reliable, plentiful energy supply at an acceptable cost. For more than a decade, there has been little leadership from Washington on energy issues. As a result, our nation has no energy policy. We have wasted a decade of cheap energy during which we should have been preparing and implementing solutions to the problems of worldwide energy shortages and pressure for new energy development in an increasingly polluted world. The sharp rise in energy costs as a result of Iraq's recent invasion of Kuwait helps move our country toward recession and reminds us that energy supplies are central to our economy. Energy issues will not go away for us -- they will only become more critical until we take effective action.

Americans look to Congress and the Administration to ensure that the United States is insulated as much as possible from adverse world events and to make it possible for our country to develop a self-reliant, energy-efficient economic system. To a considerable extent, Congress and the Administration will be judged on how well they are able to do this in the face of current budget problems.

GEOTHERMAL ENERGY

Geothermal energy is the heat of the earth. Since the depths of the earth are very hot, heat flows outward toward the surface, and the temperature increases with depth below the surface. The several thermal regimes in the earth give rise to a classification of geothermal resource types, illustrated in Figure 1.

Hydrothermal energy, geopressured energy, and magma energy, all result from the *concentration of earth's heat* in discrete regions of the subsurface by one or more of several geologic processes. *Earth energy* is thermal energy at the normal temperature of the shallow ground, *without anomalous enhancement* due to geologic processes. It is energy that is found everywhere across the United States and the world and can be used with geothermal heat pumps to heat and cool homes and buildings, supply domestic hot water and provide industrial heat needs. *Hot dry rock energy* occurs at depths of 5 to 10 miles beneath the surface everywhere, although it also occurs in areas of thermal enhancement due to geologic processes.

Naturally occurring hot water and steam form the *hydrothermal energy* resource. Hydrothermal development is economic today at a few high-grade sites. A relatively small industry generates electrical power and supplies heat for direct uses from hydrothermal resources. Many more hydrothermal resources could be used if better technology were available and if their development were actively promoted by the government. Geopressured, hot dry rock and magma energy all require further R&D to enable them to be economically developed.

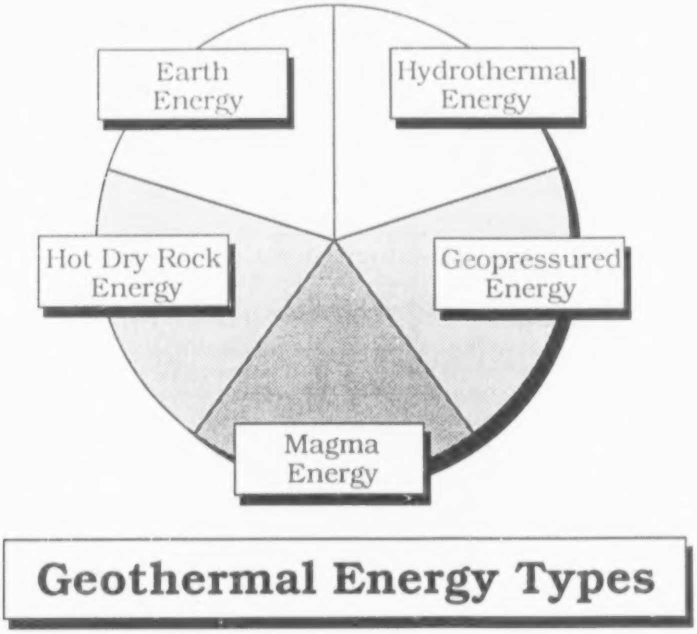


Figure 1.

CURRENT AND POTENTIAL CONTRIBUTION OF GEOTHERMAL ENERGY

Geothermal energy is here today -- it is not merely a hope for the future. *The production of geothermal energy in the U.S. currently ranks third in renewable energy sources*, following hydroelectric power and biomass energy. As a result of geothermal production today, consumption of exhaustible fossil fuels is offset along with the release of the greenhouse and acid-rain gases that are caused by fossil-fuel use. Geothermal energy use in the United States is equivalent to the burning of about 60 million barrels (bbl) of petroleum each year, while worldwide geothermal energy use is equivalent to the burning of about 150 million barrels of oil per year. The U.S. Strategic Petroleum Reserve contains less than 600 million barrels of oil, an amount that could be replaced every four years with the savings from worldwide geothermal use.

There is a very large geothermal resource base in the U.S., much of which can not yet be economically developed. In fact, *the total resource base for the renewable/sustainable energies -- geothermal, solar, biomass and wind -- is much larger than the total resource base in coal, oil, gas, uranium (nuclear power) and hydropower combined.*

It is difficult to estimate the ultimate potential contribution of geothermal energy to mankind's needs for four reasons:

1. Future energy costs are uncertain, and many lower-grade hydrothermal resources would become economic at higher energy prices;

2. Technology is not yet available for economic use of many hydrothermal resources, nor for use of any of the geopressured, hot dry rock, or magma resources;

3. Only preliminary estimates of the U. S. and worldwide resource base have been made; and,

4. Figures for demand reduction through widespread use of geothermal heat pumps are not available.

Geothermal resources can contribute greatly to the energy needs in the U.S., both on the *supply side* (generation of geothermal electricity and production of geothermal heat for direct use) and on the *demand side* (reduction in the need for new electrical generating capacity and savings in natural gas consumption through the use of geothermal heat pumps). Although most geothermal electrical power generation will be restricted to the western U.S. until deep hot dry rock resources can be tapped, geothermal heat pumps can be installed virtually anywhere, bringing the benefits of geothermal energy to all parts of our Nation.

Geothermal Heat Increases our Energy Supplies

At our current stage of technology and with current energy costs, economic development of geothermal energy can be accomplished in *some* areas where the heat is concentrated by geological processes. Hot water and steam exist at many subsurface locations in the western U.S. in the form of hydrothermal systems. These hydrothermal systems can be tapped by existing well-drilling and energy-conversion technology to generate electricity or to produce hot water for direct use. For generation of electricity, hot water is brought to the surface through production wells and is flashed to steam in special vessels by release of pressure. The steam is separated and fed to a turbine engine, which turns a generator. Spent geothermal fluid is injected back into cooler parts of the reservoir to obviate environmental problems and to help maintain reservoir pressure (Figure 2). Some high-temperature (+450 °F) resources yield steam from the reservoir rather than water, and this steam is fed straight to the turbines. If the reservoir is to be used for direct-heat application, the geothermal fluid is usually fed to a heat exchanger before being reinjected into the earth. Hot water from the output side of the heat exchanger is then used for home heating, greenhouse heating, vegetable drying and a wide variety of other uses.

Geothermal Resource

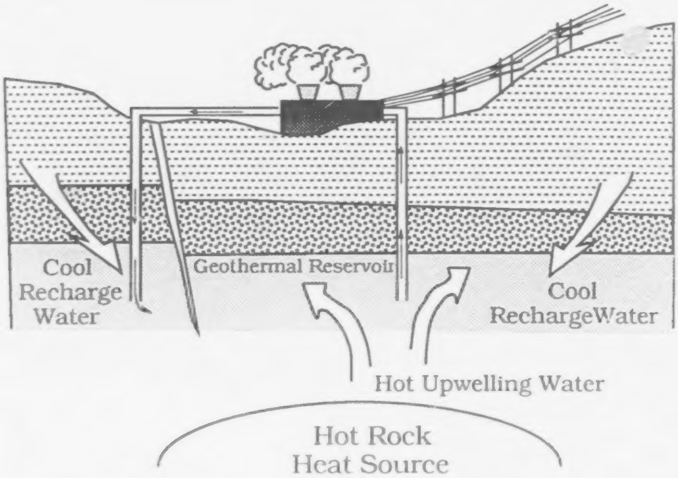


Figure 2

The U.S. geothermal industry currently has an *installed capacity of 2,800 megawatts of electrical power* (MWe) from hydrothermal resources (1), while direct applications of hydrothermal energy in the U. S. have a total installed capacity in excess of 2,100 thermal megawatts (MWt), including geothermal heat pumps (2,3).

Geothermal energy is found in many places on the earth in addition to the U. S., and its utilization is growing rapidly worldwide. *Approximately 5,700 megawatts of electricity are currently being generated in some 20 countries from geothermal energy (1), and there are 11,300 thermal megawatts of installed capacity worldwide for direct-heat applications* at inlet temperatures above 95° F (35° C) (4). If we include the use of geothermal water at lower temperatures and geothermal heat pumps operating at normal groundwater temperature, the energy production throughout the world from geothermal resources is very much greater, but unquantified at this time.

Reserves of hydrothermal energy in the U. S. are difficult to quantify. However, the United States Geological Survey has estimated that geothermal energy from identified high-temperature U.S. hydrothermal systems could supply 23,000 megawatts of electrical energy for 30 years (5). In addition, they believe that about 5 times this amount may be available from undiscovered hydrothermal resources in the U. S.

Low- to moderate-temperature geothermal resources, suitable for direct-heat application, are widely distributed throughout the western and mid-western United States (6). Discrete resources exist throughout the western third of the country in subsurface reservoirs of a few acres to a few square miles in extent, while in the northern Great Plains, major stratabound geothermal aquifers may extend in a continuous manner for thousands of square miles (7). It is estimated that more than 7,800 MWt could be installed in district heating systems in the U. S. using *identified* resources, and that the ultimate potential is much larger.

Systems for use of hydrothermal energy have proven to be extremely reliable and flexible. During 1987, hydrothermal electric power plants were on line an average of 97 % of the time, whereas nuclear plants averaged only 65 % and coal plants only 75 % on-line time (Figure 3). Geothermal plants are modular, and can be installed in increments as they are needed. Both baseline and peaking power can be generated. Construction time can be as little as 6 months for plants in the range 0.5 to 10 MWe and as little as 2 years for clusters of plants totalling 250 MWe or more.

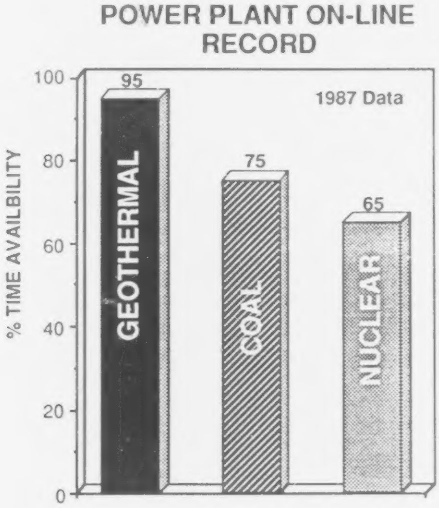


Figure 3.

Geothermal Energy Decreases our Energy Demand

No active technology for home heating and air conditioning is more efficient than the geothermal heat pump (GHP). GHPs use normal-temperature earth or groundwater for heating during the winter, cooling during the summer and supplying hot-water needs year around. The heat pump itself operates on the same principal as the home refrigerator, which is actually a one-way heat pump. The GHP, however, can move heat in either direction -- it is reversible. In the winter, heat is removed from the earth and delivered into the home or building (heating mode). In the summer, heat is removed from the home or building and delivered for storage into the earth (air-conditioning mode). On either cycle, culinary water is heated and stored, eliminating the need for a separate hot-water heater. Because electricity is used only to transfer heat, not to produce it, the

GHP will deliver 3 to 4 times more energy than it consumes. It can be effectively used over a wide range of earth temperatures.

The GHP unit sits inside the home or building, at the site of a normal gas furnace (Figure 4). In a typical installation, a loop of plastic pipe is placed in a vertical drill hole from one hundred to several hundred feet deep and the hole is backfilled with clay. A water/antifreeze solution is circulated through the loop and through the heat pump for removing heat from or rejecting heat to the ground. There is no consumptive use of groundwater whatsoever, nor is there any contact between the solution in the plastic pipe and the earth or groundwater. An alternative installation is sometimes carried out by placing the loop of plastic pipe in a horizontal trench and backfilling with soil. Either installation easily conforms to local construction and well-drilling regulations. Typical loop installations are warranted for 50 years (8).

In a 1988 survey of geothermal heat pump buyers (9), 97 % said that they were satisfied with their purchase and would buy again. Not one of the 157 randomly selected buyers refused to respond to the survey.

Earth-Coupled Heat Pump

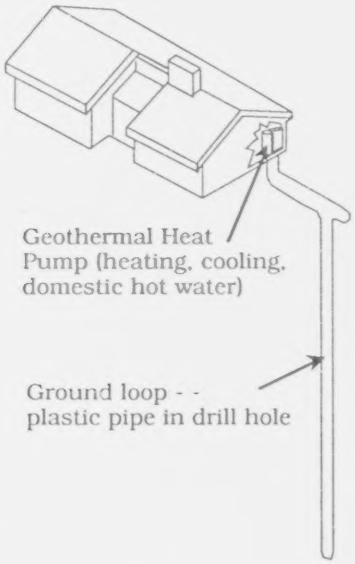

Geothermal Heat Pump (heating, cooling, domestic hot water)
Ground loop - - plastic pipe in drill hole

Figure 4

The U. S. lags behind other countries in taking advantage of heat-pump technology. Sweden has deferred construction of two nuclear power plants by using GHPs to reduce electrical power needs. Canadian growth in GHPs since 1986 has exceeded 50 % per year.

More than 100,000 electrically powered geothermal heat pumps have been installed in homes and buildings in the U. S. **(mid-1990 figure). Additional installations are being actively promoted by investor-owned utilities and rural electrical cooperatives as a means of promoting energy efficiency and better managing demand. GHPs can cut 1 to 5 kilowatts (KW) of peak generating capacity requirement per residential installation. There are an estimated 25 million homes in the U.S. that have central air conditioning without access to natural gas (10). Replacement of these units alone with GHPs over the next several decades is not unreasonable. The savings would be 24,000 to 48,000 MWe in peak summer demand and 48,000 to 96.000 MWe in peak winter demand. This estimate illustrates what could be done in only one sector -- homes in the U. S. with electrical central air conditioning. It does not include new home construction or electrical energy used in heating and cooling buildings of the industrial or public sectors. In addition, natural-gas powered GHPs are under development and enhanced-performance units, with end-use efficiencies of 160 %, should be available within a few years.**

Although the above figures give an indication of the amount of electricity and gas that could be saved through widespread use of geothermal heat pumps, the topic clearly merits a more detailed investigation. We recommend that DOE undertake a thorough examination of this technology, its R&D needs and ways to implement it quickly across the U. S.

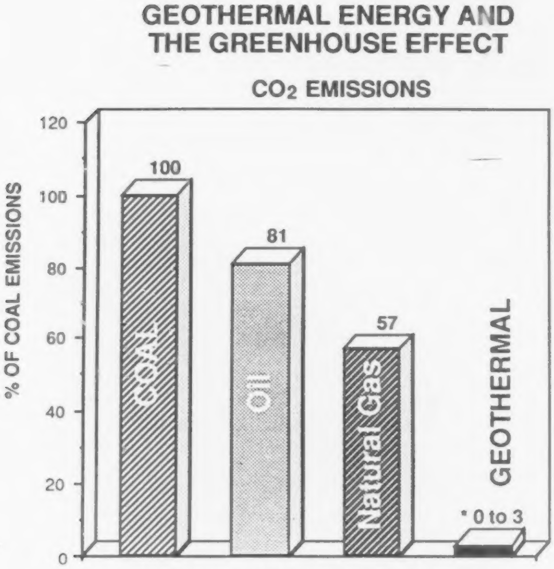
GEOTHERMAL ENERGY -- NET POSITIVE ENVIRONMENTAL IMPACT

Every major urban center and industrial complex around the world is emitting unacceptable quantities of climate- and biosphere-modifying air pollution. Certainly, the competing goals of increased energy production for continued worldwide social development and the need to mitigate release to the atmosphere of greenhouse and acid-rain gases are not compatible using today's energy mix. Strategies which allow high standards of living without fossil–fuel burning must include technologies that produce electrical energy with little or no harmful emissions.

Development of geothermal energy has a large net positive impact on the environment compared with further development of conventional energy sources. Modern geothermal power plants operating on hydrothermal resources have extremely low levels of CO_2, NO_x, SO_x and particulate emissions. The newest generation of power plants have equipment to recover the noncondensible gas from the steam and inject it back into the earth along with the spent geothermal fluid. Consequently, these plants emit only 0.3 lb of carbon per megawatt-hour (MW-hr) of electricity generated. This figure compares with 282 lb/MW-hr of carbon for a plant operating on natural gas, 418 lb/MW-hr of carbon for a plant operating on #6 fuel oil and 497 lb/MW-hr of carbon for a plant using bituminous coal (11). *Emissions of CO_2 from coal-fired generating plants are more than 1,600 times greater than emissions from modern hydrothermal power plants* (Figure 5). The advantage of geothermal energy in these comparisons is obvious.

Growing acid rain problems will increasingly limit the use of power-plant technologies incapable of low sulfur emission. Geothermal power plants have sulfur emission rates that average only about 1 percent of those from fossil–fuel alternatives. Nitrogen–oxide emissions are also much lower than those from fossil plants. The only particulate emissions from geothermal plants are those associated with evaporation of water in the cooling towers, which are typically a factor of 1,000 smaller than particulate emissions from coal, oil and biomass stacks (11).

Geothermal power plants require very little land, taking up only a few acres for plant sizes of 100 megawatts or more. Other land uses can mingle with geothermal plants with little interference or fear of accidents. Geothermal drilling, with no risk of fire, is safer than petroleum drilling, and there is less worry about the potential for environmental damage from drilling activities.



* *Newest geothermal plants use reinjection of gases and produce no CO_2*

Figure 5.

OPPORTUNITY IN FOREIGN GEOTHERMAL DEVELOPMENT

Geothermal resources occur in geologically active regions worldwide. A large resource base is believed to exist in many of the developing countries, including those of Central and South America, the Caribbean, eastern Africa, the Mediterranean, the Philippines, Papua New Guinea and Indonesia. The Soviet Union has large resources of geothermal energy which are almost totally undeveloped. Long-time, successful users of geothermal resources include Italy, Iceland, New Zealand and Japan along with the United States.

The United States leads the world in geothermal technology. This lead is based on strong industry experience in many types of hydrothermal systems and on research supported by the Department of Energy and the U. S. Geological Survey. However, the Japanese are making a determined effort to gain dominance in this field and are expending several times more money on geothermal R&D than is being spent in the U.S.

New geothermal technology is being actively sought by both developing and developed countries. A large potential foreign market for U.S. expertise, services and equipment is available, and the export of geothermal technology would help lower our foreign trade deficit, slow the use of the world's exhaustible oil supplies and decrease emissions of greenhouse and acid-rain producing gases.

However, there are severe financial constraints in third-world energy development. Adequate funds at acceptable rates are lacking in most developing countries. A conservatively estimated $70 billion per year will be needed over the next 20 years to pace growing electrical demand in third-world countries, an amount that will exceed the expected supply from the international lending agencies by some $300 billion (12). Some countries, such as Costa Rica and the Philippines, have revised or are revising their laws to allow private power development in an effort to supplement increases in generation capacity by their own national utilities. Geothermal energy is especially attractive in third-world countries because it is an indigenous energy source for which generating capacity can be added in increments as small as a few megawatts or as large as 100 megawatts. The Philippines is planning orderly development of geothermal electrical power over the next decade in spite of the occurrence there of many potential hydropower dam sites because geothermal power plants can be brought on line much more quickly, with much lower capital requirements and with lower risk than can a large hydroelectric project (13).

In 1987, the National Geothermal Association (NGA) was formed to assist the U.S. geothermal industry in becoming more internationally competitive. The primary mission of the NGA is the export of U.S. geothermal goods and services. Since the NGA was incorporated, it has applied for and received a Certificate of Review (COR) from the Department of Commerce, elevating the association to the level of an Export Trading Company and opening the doors for its members to do foreign business more freely. Operating under the COR, the NGA has also spawned a for-profit company, the U.S. Geothermal Industries Corporation (USGIC) to carry out foreign projects. USGIC is now actively working on agreements for privatized power development in three countries and has sponsored trade shows, reverse trade missions and the development of educational information.

The U.S. geothermal industry could potentially be successful in developing energy resources for third-world countries. Both the U.S. and foreign countries have benefitted from the limited geothermal development already carried out on foreign soil by U. S. companies. However, small geothermal companies are finding it difficult to compete on the foreign market due to the availability of *subsidized, low-cost loans and tied aid* from such countries as Japan and Italy.

Several developing nations with which we have had discussions have told us that they would prefer to use the superior U. S. technologies and products if they could. However, *the subsidized financing that foreign competitors are able to offer knocks the U. S. industry out of competition.* In view of the large amounts of foreign aid given by the United States, it seems unreasonable that we can not compete because of subsidies and tied aid from foreign governments. We believe that this inequity can and should be corrected by the Federal government in its foreign-aid programs.

RECOMMENDATIONS FOR FEDERAL SUPPORT

The United States should embrace an energy policy that will promote development, use and advancement of a mix of domestic energy resources with incentives for renewable/sustainable energies. A proper mix will help ensure energy security while support for renewable/sustainable energies will lead to decreased use of fossil fuels, helping to preserve the environment and decrease our dependence on imported oil.

We group our discussion of areas needing Federal support and our recommendations for that support under four headings, presented below.

1. Taxes and Regulation. The present tax and regulatory structures in the U.S. do not provide sufficient encouragement for geothermal development. For one thing, there is today no strong incentive for development of environmentally advantageous resources such

as geothermal energy. The United States should develop laws and regulations specifically designed to stimulate the development of renewable/sustainable energy resources. Meanwhile, tax incentives similar to those in existence and proposed for the major energy sources should also be available to geothermal developers.

Tax credits should be allowed for installation of environmentally preferable energy technologies such as geothermal energy. In particular, the *geothermal tax credit*, which expired on 30 September 1990, and is under consideration for another year's extension, *should be made permanent.*

The 80 MWe maximum size limitation on PURPA power plants should be removed to allow geothermal power to compete better with large conventional power plants. We appreciate very much the efforts of Senator Domenici for taking the initiative on this important issue during the last year. In addition, to encourage development, *geothermal energy should be released from the alternative minimum tax.*

Limits on the maximum amount of land a developer may have under lease are still too restrictive in the view of the small number of geothermal operators. Also, major utilities can still thwart the efforts of independent energy producers by denying access to transmission lines and wheeling rights and failing to plan cooperatively for geothermal development. These problems should be corrected.

The geothermal industry is interested in working with Congress and the Federal and state regulatory agencies to correct these problems, and we would be happy to furnish more detailed information.

2. Research and Development. Only a small part of the hydrothermal resource base can be developed today because of inadequate technology. A concerted R&D effort by the Department of Energy is clearly needed to help solve this problem. Better methods are needed for discovering hydrothermal systems and for delineating them without the need for expensive drilling. Better drilling technologies must be developed to reduce the time and cost required. We must also make improvements in our abilities to predict the performance of hydrothermal reservoirs under production and to manage production/injection well fields. Energy conversion equipment can be improved further to yield greater efficiency and the ability to use lower-temperature resources. R&D is also needed to help bring the longer-range hot dry rock, geopressured and magma resources closer to commercialization. In particular, we recommend that Congress appropriate special funds for completion of the long-term flow test at the Fenton Hill hot dry rock experiment site. We also believe that the Magma energy program in DOE should not be halted as DOE proposes to do.

R&D is needed in furthering the application of geothermal heat-pump technology to reducing demand for electricity and gas. DOE should undertake a comprehensive study of the potential impact on electricity and gas demand reduction through widespread heat-pump use. Improvement in the efficiency of heat pumps should be undertaken. Better and less expensive methods for installation of the subsurface pipe loop are needed.

We recognize the need for research in all of the energy technologies. We are aware of recommendations in the National Research Council's report entitled "Geothermal Energy Technology -- Issues, R&D Needs, and Cooperative Arrangements" dated 1987. This report recommends a federal geothermal research budget of $35 million. *The Administration's FY 1991 Federal geothermal R&D budget request ($18 million) was much too small* and indicates the Administration's lack of recognition of geothermal energy as a viable alternative. It presently appears that Congress will boost the total geothermal budget to $29.5 million, for which we are supportive and grateful. The NRC's recommended level, in our opinion, is a minimum amount, and *we recommend that the FY 1992 budget be at the very least $35 million.*

3. Foreign Market Development. DOE's efforts, through the ECRE and CORECT programs, to promote export of U.S. energy goods and services are largely thwarted by competition from foreign companies having subsidies from their governments. No-cost or low-cost loans and tied-aid grants for geothermal development given to third-world countries are the deciding factor in too many foreign projects. Much of the foreign aid given by Japan, Italy, France and other countries is specified for major infrastructure development in which their industries participate. By contrast, the U.S. gives large sums for social and medical programs, comparatively little of which comes back to U.S. soil in the form of exports of our advanced technologies. While social and medical programs are indeed important, the U.S. should insist that other countries support their share of such programs with their aid. This would free the U. S. to fund more infrastructure. We should follow the lead of our foreign competitors and initiate aid programs that require use of U. S. goods and services.

The geothermal community endorses Senate Bill 2703, which would tie a portion of U.S. AID funds to the purchase of U.S. goods and services.

4. Federal Leadership. The Congress and the Administration should begin to provide the leadership in energy issues that has been missing for a decade. The National Energy Strategy being formulated by the Department of Energy is rumored to be bogged down as well as watered down and to provide no measure of leadership (14). We sincerely hope that this is not the case. *Our country needs and deserves the best possible energy policies. The leadership in this effort must rest with the Federal sectors of government.*

Beyond leadership in devising and implementing a national energy policy, *the Federal government should set an example in the promotion and use of renewable/sustainable energy technologies.* The geothermal option has been dropped from the agendas of most utilities. The Electric Power Research Institute eliminated their geothermal program two years ago. This is hard to understand when we consider the recent and planned increases in power-system interconnections. High-temperature geothermal resources may be found only in the West, but the whole country would benefit from their development. The geothermal industry needs help in institutionalizing geothermal among energy choices. We also need recognition within the Department of Energy of our viability and of the advantages and potential that geothermal energy has to offer.

There are substantial reserves of geothermal energy on Federal lands -- lands administered by the Bureau of Land Management, the Forest Service and the Department of Defense. Development of geothermal resources on these lands not only contributes to our domestic energy supply, it also generates royalty and tax revenues for the Federal and state governments. Federal royalties on the limited amount of geothermal development to date already generate about $20 million per year.

Finally, *the government should convert Federal buildings and installations as well as Federal housing projects to geothermal energy*, mostly earth energy. Installation of geothermal heat pumps would not only save the government millions of dollars in electricity and gas costs, it would contribute to a cleaner environment.

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Senator BINGAMAN. Thank you very much. I appreciate that testimony.

Next is Jan Hartke, who is well known to all of us here in New Mexico. I chided him before the hearing as to why he is not out on the campaign trail. He and I used to do some of that when he was State Treasurer and I was Attorney General. We are pleased to have him here, and he is accompanied by Roy McAlister. Jan is now member of the Board of Directors of the Global Tomorrow coalition, an attorney in Washington, and Roy McAlister is President of the American Hydrogen Association.

Jan, why don't you go right ahead?

Senator DOMENICI. Mr. Chairman, before he starts, I have to leave. I just wanted to thank our two visiting students, and tell you that since I will not have a chance to ask you questions, I will write to you and tell you what I think about your statement and ask you a couple of questions. Fair enough?

Senator BINGAMAN. Thank you for being here.

Jan, why don't you go ahead?

STATEMENT OF JAN HARTKE, VICE PRESIDENT, ENVIRONMENT, THE HUMANE SOCIETY OF THE UNITED STATES, ON BEHALF OF GLOBAL TOMORROW COALITION AND RENEW AMERICA

Mr. HARTKE. Thank you, Senator Bingaman, first, for holding these hearings, and trying to have impact upon what the Secretary of Energy will have to say to the President as he begins to formulate a new energy strategy for the United States.

I would like to summarily point out that the Global Tomorrow Coalition President, Don Lesh, is in our audience over here. That organization has 120 non-governmental organizations that are members with over 10 million Americans being members of those organizations. Most of the major environmental organizations in the country are part of this coalition, and I am speaking on behalf of them in addition to the fact that I am speaking on behalf of Renew America, which recently had a Rose Garden ceremony when the President gave out awards to our environmental success stories that we found around the country so that we could show there is something being done to promote a sustainable humane world. In addition, I am speaking as Vice President of Environment for the Humane Society of the United States and its 1,200,000 members, who are increasingly concerned with the environmental destruction that is going on worldwide, and it is having a devastating impact not only upon people, but upon animals and plants.

A week ago Denis Hayes spoke at our national convention. Denis Hayes being the chairman of Earth Day 1990 with whom I worked on that occasion, and also the former head of Solar Energy Research Institute. I told him going I was going to be speaking here, and that given his qualifications as one of the really preeminent world environmental leaders today, I asked him if he could give me a statement that could give some perspective on why what we need to do is so urgent. And it is the urgency that I want to underline in my testimony.

And here is his brief comment that is in the record. "With a 'moral equivalent of war' mobilization, we could over the next 10 years halve the energy requirements of the entire world without sacrificing comfort, convenience, or productivity. Within a quarter century we could derive most of the energy needed to meet the remaining global energy needs from the sun. The obstacles to such a program are not technical but political."

I think that the President of the United States, as he begins to formulate his new National Energy Strategy, has the historic opportunity to set forth with boldness and clarity a new national purpose: to make a rapid transition to a society based on clean, safe, efficient and renewable energy technologies. Such a stated national purpose would get America going in the right direction for a change.

The urgency of the situation demands an end to the politics of drift that we have seen over the last decade particularly, and the business-as-usual mentality. The transition to renewables is inevitable, given the depletion of non-renewable resources, the vulnerability of those resources to political and military interference, and, most importantly, the national and global environmental consequences of our present reliance on fossil fuels. The greater the delay, the more the planet will suffer from adverse exponential trends. Therefore, our leaders should focus on the speed of the transition—how fast can we end our dependence on polluting forms of energy and move this country to a new non-polluting, renewable energy structure that will position America for leadership in the 21st century.

Vulnerable, as we stand today; indebted, as we stand today; behind, as we stand today, we are becoming paralyzed witnesses to the emergence of new world powers. If ever there were a time for new leadership, this is it. The talent and resources are still here, as we have seen today. The laboratories here in New Mexico, in my judgment, have a natural leadership role to play, but they have to be given a new national purpose within which to work. The character and competitiveness of the American are still alive. The answers, as demonstrated today, do not lie beyond our knowledge or technological capacity. But we must have political leadership to proceed in any economic recovery and any environmental restoration of this planet.

In this context, a new National Energy Strategy that attempts to be all things to all people, that is virtually for every type of fuel and resource available, will condemn the American economy to a second-class role in the world, and through the power of bad example, will encourage a slide towards global environmental catastrophe.

Political leadership is a necessary precursor to economic leadership, as Dr. Butler has indicated. Will our political titleholders set forth the goal of finding the last barrel of oil, no matter what the cost is to our environment and our soldiers' lives? Such a policy decision insures defeat. It gives new meaning to the old adage: make sure you want to get where you are going, because you just might get there. America might get to the point where we place too many of our eggs in the fossil fuel basket—just in time to have the world turn its eyes to clean, green, renewable technologies.

Already, as statistics have been given out in the past and which I have here, the Germans and the Japanese are laying the groundwork to that world leadership position by gearing up for the technologies that will be in demand in an increasingly environmentally sensitive world. America, having lost precious time due to its backward-looking policies in the 1980's, has found itself with no available option other than leading the world as the principal defender of the old order—relying on oil and securing it with blood if necessary. It did not have to be this way.

One of the premier United States senators in terms of his great running ability, Jeff, I am sure you appreciate the fact, that there is a huge difference between a 10-minute mile, which anybody can do, and running a 4-minute mile—one is commonplace and other held the power to excite the world. So it is with setting new national purposes that challenge the best that is in us. That is the way we determine the greatness of our leaders.

The equivalent of running a 10-minute mile has been announced by the Department of Energy. According to projections they have prepared, renewable energy sources at the present type of policy drift, we could have renewable energy resources satisfying about a quarter of America's energy needs by the year 2030, Dr. Butler, as your testimony also indicated. When people hear statistics like these, I would submit that their eyes glaze over. They rightfully think that maybe their great grandchildren might have something to do with this debate, but surely we do not have anything to do with it. It is just too long a time line. So we need the kind of a leader, such as we are calling for here today, who can change the assumptions, who says the timetable must be dramatically stepped up, who says that he comprehends the dynamism of great enthusiasm matched with great talent. We need bold, decisive leadership that has a vision of what we should be as a society, and then expects target dates for the achievement of the goal. That is the way it has always been in America when great challenges were before us, and there has been no challenge before us that has ever been as great as this one. With foresight and courage, the Founding Fathers had the ability to look ahead and say what kind of political documents can we produce that would give this country a burst of freedom and prosperity, and they did it.

Franklin Roosevelt, many of you will recall, made the comment after Pearl Harbor that we would be producing 50,000 airplanes a year. The War Production Board helped to make that possible to convert from a peace-time to a war-time economy. He did it in record time; he changed the assumptions; he helped save the world from tyranny.

With foresight and courage, John F. Kennedy declared that America would put a man on the moon by the end of the decade. The technology did not then exist in total, but he had faith that if he set forth the challenge, Americans would respond. They did. Neil Armstrong walked on the moon, and Jack Kennedy walked into the history books.

Is George Bush going to set forth a National Energy Strategy that is going to put us on the right track so that George Bush can set forth a vision for this country and walk into the history books? As we sit here, I hope so. A political leader with courage and vision is now needed more than ever to reindustrialize American around green factories that produce green products. Only through such a new strategy will America become a country that is strong, debt-free, and preeminent in both economic and environmental world leadership. America can produce what the world will want and demand—products that will provide energy without destruction. No longer is this just a race for jobs and for the prestige of leadership. It is now a race to save the planet as was recently on the Public Broadcasting stations. That is the kind of race I think that America wants and deserves to win.

In this regard, I would just try to close with these remarks, Mr. Chairman. During the 1980's Government policy was tragically short-sighted. It moved us in precisely the wrong direction. If I were to look back at the terrible mistakes that were made during the last decade, you would have to say that tripling the national debt was a pretty bad thing to do. You would have to say that having $200 billion budget deficits eroding the tax base of this country, and now endangering the future of our children was a pretty bad thing to do. You have to say that turning from the greatest creditor Nation on earth to the greatest debtor Nation on earth was a pretty tragic occasion.

But I think that when the historians look back in a hundred years from now, they might well say that those things were terrible devastations to the economic fiber of this country. But I think maybe the historians will look back and say that the greatest tragedy of all was when President Reagan methodically and deliberately decided to tear apart the Solar Energy Research Institute, because that had the power to formulate a new policy for America that could give hope for our children and our grandchildren, our children's children's, children as far as millennium. That is the path we have to be on.

I do not see now in this administration, nor in the Congress, the kind of understanding of the urgency of the situation. Where if we continue to drift, we will not have a world our children want to inherent during the 1990's. During 1981 to 1989 we saw an 82-percent cut in Federal research and development funding of renewables and the elimination of tax credits, while huge subsidies were ladled out to the fossil fuel and nuclear power holders.

Certainly, the first step that we have to undertake is to have a new national purpose that focuses, I believe, on first something we have not even mentioned, that is energy efficiency. It is in my testimony. I know time is short. Energy efficiency, in my opinion, has been grossly underestimated by the policy makers, who are operating on an information base that is at least 10 years out of date. I would implore members of the U.S. Senate, and the Congress, and this administration to begin to look at some of the suggestions of energy gurus such as Christopher Flavin of World Watch Institute, Amory Lofts, who has said that energy efficiency is one of the great potentials of this country, and we completely ignored it.

The second area that I am concerned with and will let my friend Roy look at and talk about is the area of solar hydrogen. We have already heard from Senator Domenici about the possibility of better batteries and electric cars and vehicles. I think that is very important. I think the other horse in this race is solar hydrogen, and I think if the President's policy is going to have any meaning and any vision whatsoever, it is going to have to be able to bring up these two different areas and begin to explore them with a much greater fervor and vigor than has been done in the past.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Hartke follows:]

PREPARED STATEMENT OF JAN HARTKE, VICE PRESIDENT, ENVIRONMENT, THE HUMANE SOCIETY OF THE UNITED STATES, ON BEHALF OF GLOBAL TOMORROW COALITION AND RENEW AMERICA

Thank you for the opportunity to appear before you today to present the views of The Humane Society of the United States, the Global Tomorrow Coalition, and Renew America on the formulation of the new National Energy Strategy. We want to thank the Subcommittee on Mineral Resources Development and Production and the Subcommittee on Energy Research and Development of the United States Senate Committee on Energy and Natural Resources, for their commitment to establishing an energy policy that will insure that environmental considerations will go hand in hand with economic considerations. We want to express our appreciation to those within the Department of Energy who see the importance of federal leadership in national energy policy. We hope that the DOE's policy options, which will be submitted to President Bush at the end of this year, will reflect the profound significance of exercising foresight at this juncture in our nation's history.

The Humane Society of the United States is a non-profit organization dedicated to the protection of animals and the environment. The Humane Society of the United States is one of America's largest animal and environmental protection organizations, with over 1,200,000 members and constituents, with staff in this country and abroad. The Humane Society of the United States (HSUS) is engaged in a broad range of environmental and scientific policy studies, research projects, and conservation efforts with the intention of alleviating and preventing the unnecessary suffering of animals.

The Global Tomorrow Coalition is a national, non-profit alliance that unites private citizens and more than 120 nongovernmental organizations, educational institutions, and corporations representing over 10 million Americans concerned with issues of population, resources, environment, and sustainable development. The Coalition's goal is to contribute to broader understanding of the interaction of long-term global trends in these issues, and to help promote informed and responsible public choice among alternative futures for the United States and alternative roles for the nation within the international community.

Renew America is a non-profit environmental organization dedicated to the development of a safe and sustainable society. Renew America collects, evaluates, and disseminates information on solutions to environmental problems. Renew America fosters the transfer of information on successful environmental programs between government, business, and environmental activists, and encourages cooperation among environmental interests. The HSUS has examined the environmental consequences on wildlife of pursuing different energy paths. It is, perhaps, not surprising that those energy technologies that endanger wildlife also endanger humans and the great ecological life support systems of the planet. As the President of The HSUS, John Hoyt, has said about one of these threats, global warming:

> Just as it is wrong for a person to roll up the windows of his car on a hot day and leave his cat or dog inside, so too it is wrong for the hand of humanity to turn up the world's thermostat and create a greenhouse effect, which will cause millions of animals to suffer and die and go extinct. Just as it is cruel and inhumane to heat up a car in which an animal is trapped, so too it is cruel and inhumane to heat up the planet's climate which encloses the whole animal kingdom. Rapid global warming is caused by choosing the wrong energy sources which pollute the skies and, in effect, roll up the windows of the planet.

The consequences of global warming could have a devastating impact on animals. Estuaries where fish spawn could be inundated. Forests that cannot live in higher temperatures may die and, as they die, the animals will die as well. Coral reefs are already showing signs of bleaching, a prelude to dying, caused by higher temperatures. Droughts will bake certain areas and, in other areas, floods will be seen. Animals will not be able to keep up with nature's new chaos. For this and many other reasons, we need an energy policy to stop the rise in global temperatures.

It is even more evident that animals will suffer and die if Brazil goes forward with its plans for hydropower projects along the whole Amazonian basin, flooding vast areas of rain forests and cataclysmically disturbing the river's complicated rhythm of life. Huge dams are not just being proposed in Brazil; they are also in various stages of development throughout the less industrialized world, such as India, and in the more developed world, as in Quebec. We must have an energy policy that avoids the construction of these huge dams.

Therefore, The HSUS supports energy conservation, improved energy efficiency, and development of clean, safe, renewable, and inexhaustible energy supplies that can be extracted, processed, delivered, and used in environmentally benign ways.

> With a "moral equivalent of war" mobilization, we could over the next ten years halve the energy requirements of the entire world without sacrificing comfort, convenience, or productivity. Within a quarter century we could derive most of the energy needed to meet the remaining global energy needs from the sun. The obstacles to such a program are not technical but political. (Denis Hayes, chairman, Earth Day 1990.)

When President Bush announces his new National Energy Strategy, we should pay attention, because it may well determine whether America will lead the world in the 21st Century, both in terms of economics and the environment. President Bush has the historic opportunity to set forth with boldness and clarity a new national purpose: to make a rapid transition to a society based on clean, safe, efficient, and renewable energy technologies. Such a stated national purpose would get America going in the right direction.

The urgency of the situation demands an end to the politics of drift and the business-as-usual mentality. The transition to renewables is inevitable, given the depletion of non-renewable resources, the vulnerability of those resources to political and military interference, and, most importantly, the national and global environmental consequences of our present reliance on fossil fuels. The greater the delay, the more the planet will suffer from adverse exponential trends. Therefore, our leaders should focus on the speed of the transition—how fast we can end our dependence on polluting forms of energy and move this country to a new non-polluting, renewable energy structure that will position America for leadership in the 21st Century.

The worst approach of all is to cling to the past. Since time, resources, and money are all limited, the essence of a non-strategy is to take the route of political cowardice and announce a strategy that calls for a little of everything. Serious priority setting is essential to true leadership. If politicians forget this, no matter how much they talk, they will fail and the society will suffer and decline. The key to developing a new political strategy for leadership in a new world order is establishing priorities, but they must be the right priorities.

Far too much of America's brains and money is going into military projects. Too much of America's brains and money are spent trying to breathe new life into the "brown" technologies that are killing the environment. Political leaders should create the conditions that will allow businesses of all sizes to create economic well-being for all, while protecting the environment. For America it is high time that government leaders exercise foresight by setting forth a vision that allows us to be world leaders in developing the "green," clean technologies of the future.

If America continues to be wedded to old technologies that pollute the world, if America continues to patronize renewable energy industries as though they were small children trying to get into an adult's game, if America continues to pretend that choices need not be made between competing technological paths, if America continues to act as though priority setting can be endlessly postponed, then America will decline and her opportunity for continued world leadership will be missed. For no nation can for long maintain its claim to world leadership if its political titleholders repeatedly fail to exercise leadership. Having slipped substantially backwards throughout the 1980s, falling much deeper in debt while focusing our resources on the military complex and the brown technologies of the past, America can ill afford a business-as-usual approach in the 1990s.

American political titleholders have ignored and still ignore the potential of energy efficiency. They ignored and still ignore the potential of solar, wind, wave, geothermal, and hydrogen energy. They pretend that priority setting can be avoided and nobody will be the wiser. To a point, this is true. Average people are too busy with their own lives to analyze the failure of a political titleholder to determine the proper priorities. It is vastly easier for a politician to say that everything is important, that he is concerned with all possibilities, that he is for everything, as though making courageous choices is not the essence of leadership. It is vastly easier to cover up lack of leadership with earnest talk on all the options. It is vastly easier to tell the voters there is no need to make courageous choices, to set priorities, to develop a national strategy designed to achieve a great vision. It is vastly easier to allay concern, to court the monied interests, to temporize and let things drift. Easier, until the ship of state hits the iceberg. Easier, until a tyrant in a Third World country threatens our economic structure by taking away a product we relied upon unnecessarily. Easier, until economists begin to question, again and again, why America is being outcompeted in the world marketplace. Easier, until dire warnings from the best scientists in the world tell us that we are dangerously polluting and destroying our environment. Easier, until we find ourselves going from being the greatest creditor nation on earth to the greatest debtor on earth. Easier, until we see the graphic, real world evidence of the costs involved in a policy of drift.

Vulnerable, indebted, behind, we are becoming paralyzed witnesses to the emergence of new world powers. If ever there were a time for new leadership, this is it. The talent and resources are still here. The character and competitiveness are still alive. The answers do not lie beyond our knowledge or technological capacity. We need the political courage to make the tough choices.

In this context, a new national energy strategy that attempts to be all things to all people will condemn the American economy to a second-class role in the world and, through the power of bad example, will encourage a slide towards global environmental catastrophe.

Political leadership is a necessary precursor to economic leadership. Will our political titleholders set forth the goal of finding the last barrel of oil, no matter what the cost is to our environment and our soldiers' lives? Such a policy decision insures defeat. It gives new meaning to the old adage: make sure you want to get where you are going, because you just might get there. America might get to the point where we place too many of our eggs in the fossil fuel basket—just in time to have the world turn its eyes to clean, green, renewable technologies. Already the Germans and the Japanese are laying the groundwork to take world leadership positions by gearing up for the technologies that will be in demand in an increasingly environmentally sensitive world. America, having lost precious time due to its backward-looking policies in the 1980s, has now found itself with no available option other than leading the world as the principal defender of the old order—relying on oil and securing it with blood if necessary. It did not have to be this way.

It is time to break away and set out on a new direction. The new national energy strategy must clearly recognize that the transition to an efficient, clean, safe, and renewable energy society be as fast as possible. Fossil fuels will have a role in the transition, but they are not the growth industries of the environmental age. To the degree that political titleholders are owned or rented by the powerful vestiges of the old order, America will, to that degree, go into decline.

There is a huge difference between running a ten-minute mile and a four-minute mile—one is commonplace, the other held the power to excite the world. So it is with setting new national purposes that challenge the best that is in us. That is the way we determine the greatness of our leaders.

The equivalent of running a ten-minute mile has been announced by the Department of Energy. According to projections prepared for the Department, renewable energy sources could satisfy more than one-quarter of America's energy needs by the year 2030. When people hear statistics like this, their eyes glaze over. They properly think that their grandchildren might be able to benefit from these renewable technologies, but that they are largely irrelevant to their lives. We need the kind of leader who changes the assumptions, who says that the timetable must be dramatically stepped up, who comprehends the dynamism of great enthusiasm matched with great talent. We need bold, decisive leadership that has a vision of what we should be as a society and that sets target dates for the achievement of the goal. That is the way it has always been in America when great challenges were before us. With foresight and courage, the Founding Fathers of this country labored to produce political documents that would last for centuries and millennia. They produced the greatest chronicle of freedom and prosperity that has ever been witnessed. With foresight and courage, Franklin D. Roosevelt declared after Pearl Harbor that America would produce 50,000 airplanes a year and would form a War Production Board to convert from a peace-time to a war-time economy. He did it in record time; he changed the assumptions; he helped save the world from tyranny. With foresight and courage, John F. Kennedy declared that America would put a man on the moon by the end of the decade. The technology did not exist at the time, but he had faith that, if he set forth the challenge, Americans would respond. They did. Neil Armstrong walked on the moon and Jack Kennedy walked into the history books. Great leaders have always challenged conventional thinking and had the ability to think anew. They did not accept the assumptions that would lead to mediocrity or failure. They challenged the assumptions and laid claim to a legacy of greatness.

Now it is time for the political leadership of this country to rise to the challenge of the Environmental Revolution, which will be as profound in its implications as the Agricultural Revolution and the Industrial Revolution. Within the context of this global Environmental Revolution, America can take a leadership position if we have the foresight to ask what policies are humane and sustainable in the long run.

Over the centuries, the countries that rose to world leadership were those that grasped the power of the new technologies. Over the last hundred years, we have prospered from a political leadership that had the ability to see the importance of securing an energy base that could power our industrial and mobile society. Yet our economic success that followed in the wake of such political leadership has now, predictably, met a new challenge, the necessity to abide by the laws of nature. Therefore, the new challenge is to be political leaders in the planetary environmental revolution. The foundations of the old economic order are crumbling and collapsing at an exceptional speed in terms of any historical comparison. Between 1970, the date of the first Earth Day, and 1990, the date of the second Earth Day, there has been a revolution in thinking. Business increasingly realizes that the choice is not between profits and environment, but to make profits through environmentalism. No economic system can be philosophically sound if it is based on unsustainable resource use. The new insistence on sustainability places a greater premium on foresight, which is the essential ingredient in a new agenda of international competitiveness. As a society, we must have the foresight to recognize that economic policies that destroy the environment have no future. Such policies are part of an old order. Clinging to them, because of an oversolicitous concern for certain vested interests, is a sign of decadence—a sure way of identifying the future losers.

The new National Energy Strategy should reflect what is best in the character of this country, a concern for future generations and their right to inherit a world in which the environment is not so degraded and destroyed by short-sighted, wrongheaded energy policy that the very survival of humans, animals, and plants is endangered.

Tina Hobson, Chairperson of Renew America and a former top executive in the Department of Energy, is fond of quoting Winston Churchill who once remarked, "In the end, Americans will always do the right thing after exhausting all the alternatives." As regards our energy policy, we are proving Churchill an astute judge of character. This generation of leaders is being tested, and the decision they make as to the energy path we follow will help determine whether we continue to witness the slow dying of the earth or whether we rise to save her.

A political leader with courage and vision is now needed more than ever to issue a new challenge: to reindustrialize America around green factories that produce green products. Only through such a new strategy will America become a country that is strong, debt-free, and preeminent in world leadership. America can produce what the world will want and demand—products that provide energy without destruction. No longer is this just a race for jobs and the prestige of leadership. It is now a race to save the planet. That is the kind of race I want America to win. It is worthy of our greatness as a people.

Testimony such as this cannot be aloof from the political pressure that politicians feel when one offers a solution that entails moving rapidly away from fossil fuels and the vested, powerful financial interests that support them. Yet the warnings of the best scientists in the world cannot be ignored. The degradation and destruction of the earth's environmental life-support systems will inevitably undermine the conditions for economic well-being. If business knows that the country intends to move quickly toward efficient, renewable energy, then business can plan for the transition. Such a challenge to American business will not only benefit the environment, but it will mean that global demand for such green technologies will be met by American business enterprises and not by foreign competitors. An efficient, renewable energy strategy is absolutely vital to international competitiveness. From this vantage point, the declaration of such a new national purpose would be a major opportunity for American business.

Already there are companies in America that are struggling to take the leadership on energy-efficient and renewable technologies. The U.S. Congress and the Administration should be asking them how governmental policy can be helpful to their efforts. Harnessing the creativity and genius of these emerging technologies should be the hallmark of the new strategy.

In this regard, the national laboratories should play a constructive role in research and development, especially on aspects of these technologies that may not yet be commercially competitive. The national laboratories as well as universities should help move the country to the new green technologies that would be economically competitive and environmentally benign. The military should retool by buying the products of the new technologies. For example, the military should order products that are alternatives to those that require fossil fuels. The military should create markets for the newly emerging renewable energy industry. Such policies, combined with proper tax credits, would spur the countless smaller businesses in America that have played, and will continue to play, a major role in making the necessary innovations. Small businesses in America know that they must anticipate the future and lead the transition if they are to stay financially solvent. A clear signal about America's intentions would be a blessing to those small businesses that have been hurt by an on-and-off roller coaster energy policy.

Since a transition, no matter how swift, occurs over a period of time, business would have a chance to plan ahead, to make adjustments, to get into the flow of the future. Government can give a helping hand to those who make the effort.

There is a major difference between political vision and economic profit-making: the political leader sees the way a society must act if it is to be successful at some point in the future, and a business leader sees how a business must act if it is to meet its payroll today. A successful business cannot afford to put too many resources into a vision that lies too far in the future, or it will go bankrupt in the present. Recognizing the limits on future research and development that individual companies necessarily have, the political leadership must be enormously concerned where it places the hard-earned tax money of its citizens so that, as a society, the gap between the political vision of where we are today and where we need to be in the future, is made narrower for businesses that must work day by day to get us there. Unfortunately, during the 1980s, government policy was short-sighted and moved in precisely the wrong direction. Between 1981 and 1989, we saw an eighty-two percent (82%) cut in federal research and development funding of renewables and the elimination of tax credits, while huge subsidies were ladled out to fossil fuel and nuclear power.

The three questions that President Bush should ask the finest minds in the nation are these: (1) How fast could America make the transition to a society based on energy technologies that are efficient, clean, safe, and renewable? (2) What is the best way to get us there? (3) What are the target dates we should establish to measure our progress?

ENERGY EFFICIENCY

Certainly the first step toward a new energy strategy should be a recognition that, in terms of being cost-effective and environmentally benign, attaining full energy efficiency is the most important near-term goal. According to Amory Lovins, Board Member of Renew America and Director of Research at Rocky Mountain Institute: "There are modern technologies that can save four-fifths of all oil (consumed) in the country, provide exactly the same services or better, and cost less than $3.00 per barrel." The Sierra Club has pointed out that the United States consumes two and a half times more energy per capita than Japan and Western Europe. At their levels of energy efficiency we would save over $200 billion and more than twice as much oil as optimistic estimates of what the Arctic National Wildlife Refuge might contain, every year. The average American household could save 80% on its electricity bills by using energy-efficient appliances. If today's best lighting systems were used throughout the United States, they would save as much power as 120 giant (thousand megawatt) power plants; today's refrigerators would save another 16, freezers 10, and air conditioners 100.

Increasing fuel economy standards to 40 mpg for cars would save 2.8 million barrels per day, nearly 10 times the 290,000 barrels per day that would be produced under optimistic estimates of potential Arctic Refuge reserves. It can be easily done. Volvo has a four-passenger, high-quality car ready for production that gets 71 miles per gallon; it awaits increased demand. Renault has a prototype that gets 12[illegible] mpg. Automobile efficiency improvements made since 1973 are saving America 2.8 million barrels per day. Each mile per gallon increase in new car and light truck fuel economy saves about 70 million barrels of oil over the life of the model year.

New highly insulative "super windows" could save more oil and gas than the 1.5 million barrels a day that the Alaska pipeline now supplies. Efficient burners, boilers, and furnaces can save 80 million barrels of oil a year.

These savings begin immediately, last forever, and lead to a cleaner environment. Recent experience and numerous analytical studies show clearly that improved energy efficiency is the fastest and least expensive means of reducing dependence on foreign oil. The efficiency of the U.S. energy economy has improved an impressive 24% since 1973, saving the equivalent of an amazing 1.5 billion barrels in 1987 alone, or 4 million barrels per day. Yet, we have only scratched the surface of this potential.

The National Energy Efficiency Platform proposed by the American Council for an Energy-Efficient Economy lays out ten specific policy measures that can reduce U.S. energy intensity at a rate of three percent (3%) per year. Such efficiency improvements would cut carbon emissions 21 percent below the projected level by the year 2000 or eleven percent (11%) below the level of current emissions. Implementing these policy proposals would be an excellent start. In my opinion, the potential of energy efficiency has been grossly underestimated by policy makers who are operating on an information base that is at least ten years out of date.

RENEWABLE ENERGY

In combination with energy efficiency, we need to develop the renewable technologies that will form the foundation for the energy structure of the 21st Century. Christopher Flavin of Worldwatch Institute and Rick Piltz, writing in Renew America's Sustainable Energy, have examined three scenarios for the growth of renewable energy sources. The first is the low growth future developed by the Department of Energy. The second is the medium growth future assembled by the Solar Energy Research Institute. The third scenario is the higher growth future that is practical if policy measures are rigorously implemented. Only by pursuing the third approach can America reduce its carbon dioxide emission by fifty percent (50%) by the year 2010. The key point is that America has the technological know-how to achieve great progress in eliminating air pollution, stopping acid rain, and slowing global warming, but it will take courageous political leadership to get it done.

The present policy of dependence on foreign supplies of fossil fuels is dangerous to the lives of the young men and women who must defend it, and it is dangerous to the survival of the planet. A runaway greenhouse effect is not an imaginable scenario. It would not be the first time that governmental and economic leaders have vastly underestimated the toll that a particular environmental threat could exact on the health and welfare of the life on the planet.

What energy options does the president have beyond fossil fuels and nuclear power? Energy efficiency is immediately available. In addition, biomass, wind, wave, ocean thermal, geothermal, hydro and, of course, solar power are all at various stages of development and must be explored as to their economic and environmental cost. Clearly we need a least-cost energy strategy that weighs both economic and environmental costs. It has recently been pointed out that the Alaskan oil spill, one of the largest environmental accidents in history, actually had the effect of raising the GNP, which demonstrates that our method of measuring progress is seriously flawed.

We need to end subsidies and other forms of taxpayer support to fossil fuels and nuclear power, because these special support programs tend to make it difficult for clean and renewable energy sources to compete on a fair basis. In this regard, at least six states are considering proposals to assign an environmental cost to proposed new fossil fuel-fired power plants. We need to reinstate tax credits at much higher levels for renewable energy projects and increase research and development and demonstration project spending for renewable energy sources from the current level of $138 million to an amount commensurate with our goal of creating a strong national economy that is able to compete internationally, without hurting our environment. Even more important, we need policies that will do everything possible to create markets for the new green technologies.

I would like to incorporate by reference, as a part of my testimony, the report, Sustainable Energy, produced by Renew America. This report serves as a guide to how we should proceed on our energy policy if we are to begin to heal the planet. The report highlights the advantages of greater fuel economy, energy-wise buildings, lighting and appliance efficiencies, industrial efficiency, wind power, solar thermal power, photovoltaic electricity, geothermal energy, ocean energy, and biomass energy. Each of these areas must be pursued so that an equitable and just system can be put in place to provide energy at reasonable cost without environmental damage. In addition, the report deals with renewable transportation fuels.

Apart from the importance of carpooling, better urban and suburban planning, increasing new car fuel efficiency, and shifting our federal financial support to a more balanced mix of buses, light and heavy rail, bicycles, and other forms of public transport, we must ask ourselves what should be the fuel of the future when fossil fuels are phased out.

The answer is that cars in the next century will run on electricity or hydrogen, with both being made from renewable sources of energy, such as solar and wind. These forms of energy will not contribute to global warming or air pollution.

In the United States, there were 51 million more cars being driven, and 450 billion more miles traveled in 1988 than in 1970. Improving fuel efficiency is a great step forward, but alone it will not be enough if the fuel is still polluting and more people continue to drive more cars longer distances. Overseas, the population bomb is exploding with even greater force than in America, and more cars will end up being driven more miles. With polluting fuels, we must run to keep up.

In their article in World Watch magazine, "Filling Up in the Future," Nicholas Lenssen and John Young point out that more hydrocarbons evaporate from a car's engine and fuel system on a hot summer day than come from the tailpipe. This fact illustrates how pollution can come from several other stages in the life of a fuel, including extraction, refining, distribution, fueling, and storage in the vehicle. All of these stages must be considered in determining the environmental impact of any fuel.

Yet the challenge remains: to make changes that actually solve the environmental crises that threaten our health, the health of future generations, and the health and survival of our planet.

Too often present policy makers are content to go from the frying pan on high to the frying pan on medium-high—both cook the food. But we do not want to support policies that kill the earth more slowly; we want policies that save the earth. We must know which policies dilute or delay environmental disaster and which ones prevent it. That is the fundamental key to the new national energy strategy.

The right to breathe clean air is basic. In the transportation energy field we have the technology to produce power without pollution. It is not a question of know-how, it is a question of political courage.

ELECTRIC CARS

Electric cars are quieter, free of tailpipe pollution, and, if the electricity comes from a solar power plant, free of pollution at the generation point. In the future, after battery capacity is increased to provide longer ranges, recharging time is shortened, and overall costs drop, Americans and the world will get used to plugging in their cars instead of filling up with gas. In fact, the future is not so far off. Los Angeles plans to have 10,000 electric vehicles in operation by 1995, and Western Europe could have as many as 7 million electric vehicles by the year 2000, according to Karel Van Miert, the Belgian transport commissioner.

HYDROGEN VEHICLES

Hydrogen cars already exist. Recently, a German built hydrogen-powered Mercedes Benz was brought to Washington, D.C., and members of the U.S. Senate were offered rides in it. It drove fast, safely, and yet almost nothing but steam came out of its tailpipe. Hydrogen can be made electrolytically by running an electric current through water, which splits the molecules into oxygen and hydrogen. Commercial production of hydrogen does not involve new technology, and hydrogen is already being used in many ways today, such as in the production of chemicals and foods. Hydrogen is the primary fuel for the U.S. space program, and is the cleanest fuel that can be burned. Hydrogen serves as an energy carrier. Solar photovoltaic farms and solar thermal plants designed to produce electrolytic hydrogen can be placed in desert locations like New Mexico that receive copious sunshine; the hydrogen can then be carried through pipelines to cities. The current natural gas transport, storage, and distribution infrastructure could be used for hydrogen produced in the sunny Southwest. A solar hydrogen energy economy makes possible closed, non-polluting energy cycles. People could drive into "gas" stations, say "fill it up with hydrogen," and drive away in their clean, green machines. Storage difficulties, fuel volatility, and production costs are still problems to be addressed, but the basic technology already exists and the problems could be worked out if there were a national commitment and a national challenge to do so.

With regard to solar photovoltaic energy, we are starving this promising technology and falling behind in world leadership. In 1989, the United States spent $35.5 million for PV research, ten percent (10%) of the support level for nuclear power and six percent (6%) of the support level for fossil fuels, including the Clean Coal Technology program. The Bush Administration budget request for photovoltaic research in 1990 was twenty-nine percent (29%) less than the appropriated budget for 1989, while the Administration sought a seventy-one percent (71%) increase in funding for Clean Coal Technology. Meanwhile the West Germans and the Japanese, with their smaller economies, spent $60 million and $40-45 million respectively for PV research. We have our priorities in the wrong order; it is a formula for sustained economic decline and a dramatic refutation of President Bush's announced intention to be an environmental President.

Joan Ogden and Robert Williams, researchers at Princeton University's Center for Energy and Environmental Studies, suggest in "Solar Hydrogen: Moving Beyond Fossil Fuels" that a demonstration project be established in Phoenix to take advantage of Arizona's plentiful sunshine. They suggest a gradual phase in, starting with an initial vehicle fleet of 30,000 in the early to mid 1990s that would use low cost, off-peak power from existing power plants to serve as an interim source of power for electrolytic hydrogen production. By the year 2000, with photovoltaic technology improving, PV hydrogen could fuel another 30,000 fleet vehicles.

Ogden and Williams suggest that solar hydrogen holds great promise early in the 21st Century. Pricing issues or technological problems with hydrogen beg the question of what could be done, and how quickly it could be done, if we really decided to get it done, if the U.S. President called on American talent to accomplish energy breakthroughs, and if he chose the optimum policy mix to achieve an energy transition. In other words, imagine how fast this could happen if we had political leadership. Hopefully, we will get that kind of leadership so that we can make an orderly transition, based on planning and preparation, rather than wait until the accumulation of greenhouse gases in the atmosphere becomes comparable to radiation from above-ground nuclear weapons tests.

The best method of producing hydrogen in an environmentally benign way should be determined through research by scientists and engineers. However, the United States should undertake a hydrogen demonstration project to gain experience for wider use and to educate the public about a new technology that offers them clean air and answers to the problems of global warming and dependence on foreign oil imports. If the demonstration project were to be located in Albuquerque, the state of New Mexico could be at the forefront of a new technology that the world will want.

Hydrogen can be made from conventional energy sources including oil, coal, natural gas, or nuclear power; but its greatest promise is realized when it is produced with solar energy. New Mexico could be a leader in this effort, especially since it not only has the sunlight, but also needs to clean the air in its major cities. What greater purpose could Sandia and Los Alamos National Laboratories serve than increasing their contribution to solving our energy and environmental crises? The universities also have much to offer. New Mexico businesses could prosper and help these new technologies develop and profit from the technology transfers that emanate from public research programs in the state. Fossil fuels will not provide a secure future for New Mexico or other states. Leaders must look to what the world will want and demand, and be ready to provide it. Clean, renewable energy is a growth industry, for New Mexico and for America.

New Mexico should give serious consideration to developing a demonstration project for hydrogen buses or car fleets. Such clear evidence of being in the vanguard on this issue would spur the public's imagination, encourage more resources to flow to the state, create jobs, and put the eyes of the world on the state whose symbol is, appropriately, the Zia, the Indian Sun Sign.

Solar-generated electricity and solar- or wind-generated hydrogen would produce no greenhouse gases, eliminate transportation-based urban smog, and reduce the forty billion-dollar price that Americans pay each year for illness caused by air pollution. These energy sources would free us from being tossed about by tyrants in foreign countries. They would enhance our national security. They would reduce the huge payments we make to foreign oil suppliers that have catapulted us into being the biggest debtor nation in the world. These clean energy sources would enable us to be self-sufficient, relieving our economy from the oil shocks that have thrown us into times of higher inflation and deeper recession.

When people say that solar-generated electricity and solar-generated hydrogen still cost too much, part of the answer is that government research and development should help bring the cost down, as should government incentives for businesses that are developing renewable energy sources. Another part of the answer is that the true costs of our fossil fuels are not being reflected in their purchase price. The full economic, environmental, and defense-related costs are all but ignored. When a crisis inevitably hits, like Saddam Hussein's invasion of Kuwait, the emphasis is on the outrageous act of a tyrant and not the decade of inaction and wrong-headed energy policies that preceded it.

As Gus Speth, President of the World Resources Institute, has said: "Ironically, government is now back in the energy business with a vengeance in the Persian Gulf: 197,000 U.S. military men and women are in the region or en route." Is it easier for U.S. leaders to send Americans to fight in the desert than to deploy an efficient, renewable resource policy?

Senator **Bingaman**. Thank you very much.

Mr. McAlister, did you want go ahead and testify, give us your views on solar hydrogen?

STATEMENT OF ROY E. McALISTER, PRESIDENT, AMERICAN HYDROGEN ASSOCIATION, TEMPE, AZ

Mr. **McAlister**. Thank you, Mr. Chairman. As regards solar hydrogen, we are here to say that there is a good solution to the technology trap that we presently face having the parameters of some 5.2 billion people in the world's population burning some 60 million barrels of oil a day. In America the technology trap has the financial ramifications of a thousand bilowatts, and it is some $400 billion in direct fuel costs at some $600 billion, and the damages that burning fossil fuels is doing.

The solar hydrogen solution is to do what nature does, green plants start their day by turning water into hydrogen and oxygen. Through this process and through ancient records of this process, we have the gift of fossil fuels to burn. In burning these fossil fuels we are really releasing ancient solar energy, and we are releasing ancient water and carbon dioxide again that nature tied up. If we could adjust our ways and means to do what nature does on a prompt scale, that is to produce the energy that we need in the year that we need it.

One thing that I call upon the Federal Government to do is to consider a strategic solar energy reserve that would be more important to the stability of the economy than the Strategic Oil Reserve. To store solar energy we propose the storage of hydrogen. You could generate hydrogen, and to store it in depleted gas fields, and call upon it again when you needed it in the future. Doing so would create a market for the apparatus and the storage systems that will demonstrate and will promote this solution. It could be at a much smaller price than a strategic oil reserve costs the Government. The cost of the Strategic Oil Reserve and the cost of maintaining the practice of burning fossil fuels is the first cost of the petroleum, and then it is the cost, as an opportunity cost, of not having it after you have burned it.

To give an example of how important that statement is, I have friends in the petroleum industry. They are the part of the petroleum industry that does not sell fuel but they sell petrochemicals. They tell me, and I have checked it out and it is true, that some 6 percent of the petroleum that is produced goes into products that are not burned. And these products generate more revenues than all the fuel sales that are made.

Our future really rests in this tail wagging the dog example that they are making. We should be reserving these valuable, ancient petroleum reserves for petrocarbons that are renewable, and can create the same example in building products, in aerospace products, and medicine, and chemistry, and in industry at large that we already enjoy in this room: the carpet being a petrochemical product, our clothing being petrochemical products, the wall coverings being petrochemical products.

What I am saying further is that not only does the American Hydrogen Association propose a solution to the technology trap, but we propose that this solution bring prosperity without pollution. The significance of that in economic terms is that we can immediately take the approximately $500 billion worth of environmental damages as an economic result to the bottom line in America every year as a positive result of this transition.

Thank you, Mr. Chairman.

[The prepared statement of Mr. McAlister follows:]

TESTIMONY BY:

ROY E. McALISTER
PRESIDENT, AMERICAN HYDROGEN ASSOCIATION

PRESENTED TO:

U.S. SENATE SUBCOMMITTEES ON

MINERAL RESOURCES DEVELOPMENT AND PRODUCTION
CHAIRED BY SENATOR BINGAMAN

and

ENERGY RESEARCH AND DEVELOPMENT
CHAIRED BY SENATOR FORD

SUSTAINABLE PROSPERITY WITHOUT POLLUTION

ROY E. McALISTER
PRESIDENT, AMERICAN HYDROGEN ASSOCIATION

Thank you for the opportunity to present the views of the American Hydrogen Association. Our organization is committed to the advancement of renewable resources. We believe that it is possible to have prosperity without pollution.

The industrial revolution has been supported by burning increasing quantities of fossil fuels. Abundant supplies of cheap energy have supported rapid population increases. Oil consumption has increased from virtually zero in the late 1800's to present burn rates of 60 million barrels each day.

Burning fossil fuels has caused alarming changes to the environment. Smog laden cities, lifeless lakes, and oil spills are a result of pollution from fossil fuels. Polar snow records show that we have caused the atmosphere to carry the burden of about 30 percent more carbon dioxide than at any point in the last 160 thousand years. Consequences include global warming, acid rain, depletion of protective ozone in the stratosphere, and extinction of some species. In the last decade, 6 years have been record high temperature years.

Along with the detrimental effects of the Industrial Revolution are some positive results. Good progress has been made in learning about our planet and its history. We now know that we are depending upon 500 million year-old solar energy when we burn fossil fuels. We know how to escape from the technology trap that has the parameters of 5.2 billion people dependent upon burning 60 million barrels of 500 million year-old solar energy each day. We know how to produce renewable hydrogen at a price that is competitive with ancient solar energy in the form of gasoline.

The answer is to use free solar energy and do what Henry Ford taught the Industrial Revolution concerning horseless carriages. Henry Ford provided motorized carriages from an assembly line using components manufactured from precision production tooling. Ford's cars were affordable because common materials were used to build car components in quantities that wore out high-speed production tooling. This allowed millions of dollars of tooling to be amortized over tens of millions of parts. The tooling allowance per part was only pennies.

Today's automobile includes a complex engine, transmission, differential, alternator, battery, computer, seats and upholstery, sheet metal and plastic body parts, and more wrap-around glass than the windows in many homes of Henry Ford's day. Cars that cost $20,000 or less, generally offer engine selections ranging from 100 to 200 horsepower.

A 135-horsepower engine will drive a 100-KW electricity generator. This arrangement is called a "Gen-Set". If the engine uses new solar energy as the fuel instead of ancient solar energy captured in gasoline it is called a "Solar Gen-Set". A parabolic point-focus aluminized-polymer reflector is one of the most cost-effective shapes and material selections for concentrating solar energy for use in a heat engine.

Modern water electrolyzers provide hydrogen at an energy efficiency of about 80 percent. The cost of hydrogen from electrolysis using a Solar Gen-Set is, therefore, about 1.25 times the amortized capital cost plus maintenance and the cost of pumping water into the electrolyzer.

A $20,000 vehicle has enough sheet metal, plastic, and machined parts to represent all of the components involved in a Solar Gen-Set. Sheet metal, frame, brakes, wheels, and axle components equate to the supporting structure, tracking mechanism, and reflective coating on a parabolic point-focus solar concentrator. The combustion engine, transmission, drive shaft, differential, bearings, and tires represent enough materials and fabrication technology to represent the Solar Stirling engine, electric alternator, and electrolyzer that converts concentrated sunlight to electricity for breaking water into hydrogen and oxygen.

A $20,000 Solar Gen-Set with 100 KW capacity ($200/KW) is much less expensive than the hand-built central electric power plants that now supply electricity. There are no emissions from a Solar Gen-Set. Solar Gen-Sets have few parts to wear out and there is no fuel cost. (Solar Gen-Sets do not deplete fossil or nuclear fuels.)

Modern central power plants cost $1,200 to $2,000 per KW, depending on whether the fuel is natural gas, coal, or nuclear. After buying the central power plant, fuel has to be bought to produce each kilowatt of electricity. (And the price of conventional power plants is going up due to pollution abatement and radioactive waste disposal cost escalations.)

Over a 20-year life, the amortized cost of a $20,000 Solar Gen-Set that produces 100 KW on the average of 8 hours per day during 300 days per year (65 days allowance for maintenance and bad weather) is $0.0042 per KWH of electricity or about $0.0052 per KWH of electrolyzed hydrogen:

$$\$0.0052 = \frac{(1.25)\ (\$20{,}000)}{(100\text{KW})\ (8\ \text{hrs/day})\ (300\ \text{days/year})\ (20\ \text{years})}$$

Doubling the amortized capital cost to cover overhead, land use, maintenance, and replacement of worn or storm-damaged components would bring the cost of Solar Hydrogen generation to about $0.0104 per KWH (hydrogen equivalent energy).

Solar-rich areas of Texas, New Mexico, Arizona, Nevada, and California receive about 2200 KWH/m^2 of solar energy. The cash crop of Solar Hydrogen would be worth about $18,000 to $20,000 per acre at the wholesale price of $0.01 per KWH.

Assuming that advertizing and delivering hydrogen to market doubles the wholesale cost, hydrogen will be delivered to U.S. cities at less than $0.02/KWH energy equivalent. This provides hydrogen at about $0.70 per gallon of gasoline equivalent. (1 KWH = 3,412.141 BTU. Gasoline = 119,000 BTU/Gal. A BTU-Equivalent Gal. of Hydrogen provides 119,000 BTU and weighs only 2.3 lbs.)

$0.02/KWH (119,000 BTU/ Gal. Gasoline) ÷ (3,412.141 BTU) = $0.698/ BTU-Equivalent Gal. Solar Hydrogen.

Hydrogen = $0.698/BTU-Equivalent Gal.

(This analysis has been made by comparisons to the mass produced automobile. Solar Gen-Sets are potentially less complex and less expensive per kilowatt of capacity than an automobile. Cost of sales and product liability insurance will be less. There is no compelling need to change the body style each year. If competitive manufacturers supply Solar Gen-Sets, it is possible that the production price of 20 million Solar Gen-Sets per year will drop below $200/KW.)

Sun-belt states should be busy becoming renewable energy exporters rather than consumers of fossil energy that costs billions of dollars each year. This venture into energy self sufficiency will provide far more jobs and prosperity than any "cold" or "hot" war in history.

The U.S. energy requirement for all transportation is about 30 BTU (times ten to the fifteenth power). At an overall efficiency of about 20 percent ... less than 5 percent of Arizona's land mass would suffice to supply all of the U.S. energy requirements for transportation. (Measured efficiencies of Solar Dish Gen Sets with more than 25 percent efficiency are on record.)

This area (6,000 square miles) represents only about 2.2% of Texas, 3.8% of California, 4.9% of New Mexico, 5% of Arizona, or 5.4% of Nevada. Or, if each of these states utilized 2% of their desert area to make America energy independent ... we could replace all of the now-used fossil fuels, including the needs of the transportation, industrial/commercial, and home-making sectors.

Solar Hydrogen is a solution to the technology trap of 5.2 billion persons depending on a pollution-compromised standard of living that relies on burning some 60 million barrels of oil each day. National leadership is needed to demonstrate how we can have sustainable prosperity without pollution.

Each billion dollars we spend supporting troops to show Iraq how much we need to burn their oil ... would buy enough Solar Dish Gen-Sets to produce 5 million kilowatts capacity of Solar Hydrogen. This worthwhile but modest demonstration of world leadership would have far-reaching implications. Solar Dish Gen Sets supplying 5 million KW would provide about one million American homes with Solar Hydrogen.

RENEWABLE SOLAR HYDROGEN IN TRANSPORTATION APPLICATIONS

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Abstract

New technologies for developing full-rated power and driveability from hydrogen in motor vehicle engines are disclosed and compared with previous approaches. Increased thermal efficiencies, and improved engine life and performance have been demonstrated from engines. Both Diesel and low-compression engines can be retrofitted with devices for developing full-rated power by directly injecting and igniting hydrogen as it enters closed combustion chambers of existing cars, trucks, buses, and locomotives.

Transportation engines produce about 80% of the atmospheric pollution in cities throughout the world. Particularly harmful emissions of carbon monoxide, oxides of nitrogen, unburned hydrocarbons, and carbonaceous particles are produced by transportation engines burning hydrocarbon fuels. Carbon dioxide gas concentrations in the atmosphere have accumulated to higher levels than at any time during the past 160,000 years as the world's motor-vehicle population has risen to more than 400 million vehicles. Acid rain, depletion of stratospheric ozone, development of atmospheric warming by the "Greenhouse Effect", smog, and generally reduced living standards have resulted. Practical solutions to these problems are offered by adopting renewable hydrogen to replace diminishing supplies of fossil fuels.

Hydrogen production from minerals, biomass wastes, and sun engines are indicated as more desirable alternatives to fuels and energy conversion practices that have substantially altered the biosphere.

1. INTRODUCTION: HYDROGEN-FUELED VEHICLES

Previous investigators have delineated four main problems with hydrogen-fueled vehicles that use internal combustion engines. [1, 2]

1. *REDUCED POWER:* Homogeneous-charge engines adapted to use hydrogen fuel have produced about 15 to 30% less power than when using gasoline. This is because the stoichiometric mixture of hydrogen and air offers only about 85% of the heat release of an equal volume of stoichiometrically-mixed gasoline and air.

2. *IGNITION DIFFICULTIES:* Hydrogen-fueled vehicles have the reputation of knocking due to pre-ignition and backfiring in the intake manifold. Attempts to replace diesel fuel with hydrogen have met with the difficulty of ignition failure because the compression-ignition pressure of hydrogen is much higher than that of diesel fuels.

3. *STORAGE:* At standard temperature and pressure conditions, hydrogen is a very light gas. It is about 15 times less dense than air. In order to provide sufficient energy to replace petrol fuels, hydrogen must be compressed and stored at high pressures, liquified and stored at cryogenic temperatures, or stored as a hydride.

4. *ENGINE REDESIGN:* Past engines converted to hydrogen fuel have required extensive modifications to overcome backfiring, power loss, and ignition difficulties. This has required disassembly and modifications to major components such as the crankshaft, connecting rods, pistons, heads, valves, and intake systems.

These problems can be overcome, eliminated, or reduced by new design approaches that are illustrated in a system for combining direct fuel injection with plasma ignition. Called the "Precision Spark Injection (PSI)" Technology, this approach allows the world's existing fleet of some 400 million motor vehicles to be retrofit with devices that overcome the problems of reduced power and ignition difficulties. Conversion can be accomplished in the field without teardown.

PSI Technology goes far towards solving the problem of storage by delivering greater range per measure of hydrogen from advanced storage systems presently under development by:

a. Increasing the thermal efficiency of the engine.

b. Increasing the part-load efficiency of the vehicle.

c. Increasing the mechanical efficiency of converted engines.

Conversion of existing low-compression engines with spark ignition is accomplished by replacement of spark plugs with devices that provide direct hydrogen injection and spark ignition. Conversion of existing compression-ignition engines is accomplished by replacement of diesel fuel injectors with devices that provide precision hydrogen injection and spark ignition. [3]

Fuel metering and ignition are electronically controlled to produce the best use of hydrogen for the power requirements of the instant. Installation of electronic controls and replacements for the spark plugs is accomplished in about the same time as an ordinary tune-up. Redesign of the engines is not necessary, and required modifications are accomplished by devices that are convenient replacements for standard components.

2. OPERATION OF ENGINES CONVERTED TO PSI-HYDROGEN SYSTEM

Figure 1 shows components of the PSI System for replacing the spark plugs of ordinary automobile engines with Precision Spark Injection devices. Intake air is allowed to enter the combustion chamber without throttling in engines converted to PSI operation. Increasing the breathing capacity of the engine results, and more air is present to support combustion at all phases of operation. This greatly reduces "backwork " due to the vacuum conditions in the combustion chamber that are produced by air throttling practices typical in homogeneous-charge engine operation.

After substantial compression, hydrogen is delivered through the PSI plug directly into the combustion chamber and is ignited as it enters. Hydrogen burns in the compressed air with an extremely rapid flame speed. This allows late injection and late ignition near top dead center or after top-dead-center conditions, depending upon the instantaneous piston speed.

Late injection reduces backwork due to compression of hydrogen in the combustion chamber during compression. Late ignition reduces backwork due to pressure rise due to combustion before top dead center. Power control is accomplished by metering the precise amount of fuel needed at the instant that the piston nears top-dead-center conditions. The amount of fuel required is less than in ordinary homogeneous-charge engines because excess air insulates the combustion chamber surfaces. During deceleration, there is no fuel consumption until the engine speed reaches idle or a desired hold-point.

Hydrogen combustion within excess air results in greatly reduced heat losses due to radiation and conduction. Specialized hydrogen injection patterns are provided for best air utilization in each combustion chamber type. PSI plugs are designated like spark plugs for each engine retrofit.

PSI-Hydrogen conversion provides the following characteristics:

1. More air in the combustion chamber than with homogeneous charge operation enables increased fuel combustion and increased power development.

2. Faster combustion rates provides by hydrogen within excess air enables injection and ignition after substantial completion of the air compression cycle. This greatly reduces backwork and eliminates detonation, back firing, and engine wear.

3. Initial combustion of hydrogen as it enters the combustion chamber is in fuel rich conditions. Combustion proceeds to excess air to provide reduced formation of nitrogen oxides per horsepower-hour of operation.

4. By combustion of hydrogen within excess air there are no unburned hydrocarbons or carbon compounds in the exhaust of converted engines.

5. Cold start-up of PSI-Hydrogen engines provides the same clean-burning, low emission characteristics. During deceleration there is no fuel consumption. During other transient operations the combustion chamber receives precise amounts of hydrogen at the most optimum injection and ignition timing.

3. CURBING THE GREENHOUSE EFFECT

Combustion of hydrocarbons and petrochemicals in general produce more carbon dioxide than the original amount of hydrocarbon.

$$(1) \quad H_xC_y + O_2 \longrightarrow 0.5x\,H_2O + y\,CO_2$$

Motor vehicles produce about three times as much carbon dioxide as the weight of gasoline or diesel fuel consumed:

$$(2) \quad C_8H_{18} + O_2 \longrightarrow 9\,H_2O + 8\,CO_2$$

(3) *114 Tons of Octane Gasoline* --------> *352 Tons Carbon Dioxide*

Although the greenhouse effect has been predicted for several decades, only in the past decade have most people felt sufficiently threatened to consider dealing with pollution of the atmosphere by carbonaceous fuels. Whether it is snowing, blowing, or setting record high temperatures, all weather on earth is driven by energy from the sun. In addition to heating the atmosphere and oceans the sun heats the earth's continents. Solar energy in the atmosphere evaporates water from oceans, lakes, and rivers and moves it great distances to be deposited as rain and snow. Solar energy drives the winds. Seasonal variations in temperature and weather are directly correlated to the amount of solar energy that is captured by the atmosphere, continents, and oceans.

Consider the following evidence of the ability of the atmosphere to collect more energy as a result of increased concentrations of greenhouse gases.

1. This last decade has seen the six warmest years of the last century. 1988, 1987, 1983, 1981, 1980, and 1986 were the warmest years since 1900. During this 90-year period, the global temperature has risen about 0.5°C. [4, 5]

2. The first five months of 1988 were the warmest on record. [6]

3. March, 1990, set a new high-temperature record. [7]

4. North America has had over 600 destructive tornados and extremely damaging floods during the last year. During the past 12 months, records were set for highest wind velocity in a tornado. (March 13, 1990, at Heston, Kansas.) [8]

Numerous technologies for producing hydrogen are well known. Selected technologies will be reviewed for purposes of offering comments and suggestions concerning advancement of renewable hydrogen into transportation applications.

4. NATURAL HYDROGEN

Hydrogen is the major source of energy in gas wells near Junction City, Kansas and in Webster County, Iowa. This "natural" hydrogen is thought to have been produced by the reaction between iron-rich minerals such as olivine ($[Mg, Fe]_2 SiO_4$) and water. The reaction between minerals supplying divalent iron and water follows:

$$(4) \qquad FeO + H_2O \longrightarrow Fe_3O_4 + H_2$$

In review of these discoveries and analysis of other combustible gases from wells in the earth's crust, researchers have concluded that the occurrence of hydrogen from sub-surface formations of the earth is probably more widespread than previously realized. [9] Table I shows some free hydrogen concentrations from gas wells around the world.

These same reactions could be fostered or enhanced by injection of water into formations that would be oxidized by water to release hydrogen. Judging from the past success of ingenious technology already supporting the production of oil and gas formations, this could prove to be an economical source of hydrogen. Energy companies interested in reversing the greenhouse problem could do well to review the vast occurrences of iron-rich formations in the Earth's mineral inventory. While producing hydrogen from minerals capable being oxidized to release hydrogen from water is not "inexhaustible", it offers the potential for playing an important role in the transition to renewable hydrogen.

5. RENEWABLE HYDROGEN FROM GREEN PLANTS

Hydrogen produced from water by green plants is used along with carbon dioxide to build plant tissues. At best, green plants convert only about 0.1 percent of the solar energy reaching the earth into stored energy in biomass. However this natural process amounts to an annual production of 150 to 200 billion tons of dry organic matter each year. [10]

Waste biomass generated by human activities offer an important potential for renewable energy. Table II lists estimates of the larger sources of waste biomass in the U.S.

Annual production of coal in the U.S. is about 600 million tons. Carbon content of coal ranges between 50 and 85 percent. Carbon content of the biomass wastes ranges between 40 and 60 percent. More carbon is wasted each year by discardation and incineration of biomass wastes than is sourced by mining non-renewable coal.[11] This is a serious waste of energy and an unfortunate contributor of great amounts of carbon dioxide. Each ton of carbon that is wasted produces 3.6 tons of carbon dioxide pollution to the atmosphere as biomass decays to carbon dioxide.

Several methods have been proven for producing hydrogen from waste biomass sources. In general these methods fall into either thermal or bioconversion processes.

6. THERMAL PROCESSING OF BIOMASS:

Examples of thermal methods include variations of the following reactions to produce carbon dioxide and hydrogen.

$$(5) \quad C + H_2O \longrightarrow H_2 + CO$$

$$(6) \quad CO + H_2O \longrightarrow H_2 + CO_2$$

$$(7) \quad C + 2\,H_2O \longrightarrow 2\,H_2 + CO_2$$

Hydrogen produced from wastes by this process would potentially be inexpensive. The cost of hydrogen could be $2 per million BTU (or less), depending upon the efficiency of collecting and processing waste biomass and credits taken for disposing of wastes that threaten the lifestyle of modern city dwellers. At $2 per million BTU, this source of renewable hydrogen for transportation applications would be competitive with natural gas and below the cost of refined fuels such as diesel and gasoline. Employing biomass-hydrogen processes would be far more desirable than having the same amount of CO_2 enter the atmosphere from incineration or decay of the biowastes.

Interesting options for disposing of the CO_2 include repressurizing depleted petroleum fields, using CO_2 in preference to CFCs as a blowing agent to produce insulation and foamed plastics, pumping CO_2 into deep formations of the earth's crust to form carbonate minerals, and dumping CO_2 torpedoes into the deepest oceans. In the instance of repressurizing depleted oil fields with carbon dioxide to regain production, considerable value could be attributed to the thermal process because it provides a concentrated source of carbon dioxide. Oil produced by this process would preferably find uses as recyclable polymers and energy-efficient building materials rather than be wasted as fuel.

Biomass would enter a reactor, be heated by solar or other thermal sources to drive the temperature of the endothermic reaction to 700° C, and the gas stream leaving the reactor could be separated by liquefaction or molecular diffusion-rate filters into streams of hydrogen and carbon dioxide. Figure 2 shows one version of this scheme.

Liquefaction of hydrogen for storage and shipment to distant markets is one of the most readily adopted and practical alternatives for transportation applications. Separation of carbon dioxide by condensation and phase separation during the heat removal process is a convenient method for purification.

7. BIOCONVERSION TO PRODUCE HYDROGEN

Examples of producing hydrogen from waste biomass by bioconversion include biophotolysis and digestion by non-photosynthetic bacteria. Studies of the process of biophotolysis using photobiosynthetic bacteria or algae have determined that the cost-effectiveness of the approach depends largely upon the cost of solar collectors that would facilitate photosynthesis.

Processing waste biomass using non-photosynthetic bacteria is potentially more cost-effective where already existing problems of waste biomass are found. Several authors have suggested the use of existing sewage treatment digesters as the most economical source of hydrogen. [12,13] Sewage digesters are already essential to a modern standard of living and could immediately source hydrogen from wastes that are collected by pipeline efficiencies. Bacteria that cause hydrogen to be produced from biomass residues and sewage are well known and could be expected to improve through genetic engineering. Hydrogen concentration in human intestinal gases ranges to 45 percent of the total. [14]

One of the most favorable potentials of bioconversion processes is production of carbon-rich residues from the dehydrogenation of biomass. These residues would be comparable to coal and could be stored in underground mines as concentrated carbon sources. Long-term storage of these residues would provide a means of decreasing carbon in the atmosphere. Bioprocessing of biomass wastes offers great promise as a means of supplying inexpensive hydrogen while removing carbon from the atmosphere.

8. THERMAL ENGINE PROCESSES

Solar concentrators readily produce sufficient temperatures to allow "best-condition" engine efficiencies of about 50%. This can be coupled with recent developments of 5 to 25 KW dish gensets suitable for producing inexpensive electricity. [15, 16] Author Harry Braun in his recently-published book, *The Phoenix Project ...*", envisions solar-hydrogen production from "forests" in which each "plant" or "technological tree" consists of a concentrator, Stirling engine, generator, and electrolyzer that receives pipeline water to produce pipeline hydrogen. [17] Economic production of hydrogen is predicted by mass-producing some 10 million of these solar point-focus gensets per year in automobile-style production lines.

In many locations of the U.S. sunbelt, a 20 to 25 KW genset would provide more than 300 days per year of operation at average collection levels of about 546,000 BTU/day. Assuming an overall efficiency of 30% for converting the 25 KW electrical output to hydrogen by electrolysis, each genset would provide sufficient hydrogen to fuel an automobile for about 16,000 kilometers of travel per year. In other words, each genset would produce enough hydrogen to supply an automobile owner a sufficient and inexhaustible supply of a pollution-free fuel. Hydrogen would be shipped to distant sites of application by pipelines, in cryogenic tankers, and by rail.

9. CONCLUSION

There are simple and compelling reasons for immediately dealing with the build-up of atmospheric carbon. Adoption of the Hydrogen Economy could begin with land transportation vehicles. Past problems of diminished performance in vehicles converted to hydrogen have been solved by systems that can be retrofitted to the world's existing fleet of some 400 million vehicles. It is possible to demonstrate increased prosperity and reversal of atmospheric accumulation of carbon by adopting hydrogen produced from such insistent and renewable resources as sewage and garbage. Such sources would make renewable hydrogen the choice of an "efficient" world market – that is, a market that responds to economic opportunities to base its progress on renewable energy at cost savings rather than using depletable resources. Increased productivity and improved living standards could be realized throughout the nations of the world by adapting motor vehicles to use renewable hydrogen.

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TABLES

TABLE I: SELECTED ANALYSES OF WELLS PRODUCING FREE HYDROGEN
(All Units in Mole Percents)

	H_2	CH_4	H_2O	N_2	O_2	Ar	CO_2
Igneous Country Rocks							
Philippine Islands	**41.4**	52.6	---	5.5	0.5	---	---
Nishna-Tagil'sk,USSR	**66.5**	9.5	---	20.7	3.3	0.2	---
Hawqayn, Oman	**45.0**	3.2	---	43.0	9	---	15.5
21°N,East Pacific Rise	**52.46**	0.86	---	41.45	---	0.52	4.71
Mid-Continent Rift System							
Webster County, Iowa	**96.3**	0.1	---	3.5	---	---	---
Scott Well, Kansas	**34.7**	0.03	2.1	61.0	4.6	1.1	0.2
Heins Well, Kansas	**29.6**	0.6	0.0	67.7	4.6	0.7	0.01
Sediments & Sedimentary Country Rocks							
Lubina Region, Poland	**73.1**	0.43	---	26.5	---	---	---
Washtenaw Cty, MI	**26.0**	69.0	---	3.6	0.8	---	0.6
Stavropol, USSR	**27.3**	51.0	---	20.3	0.8	---	0.0

TABLE II: WASTE BIOMASS PRODUCED IN THE U. S.

DESCRIPTION OF WASTE	ANNUAL BIOMASS PRODUCTION (Millions of Dry Tons Per Year)
Field Crop Residues	521
Animal Manure & Municipal Sewage	287
Forestry Wastes	283
Municipal Garbage	170
Miscellaneous	50
Industrial Organic Wastes	44

TOTAL	1,355

FIGURES

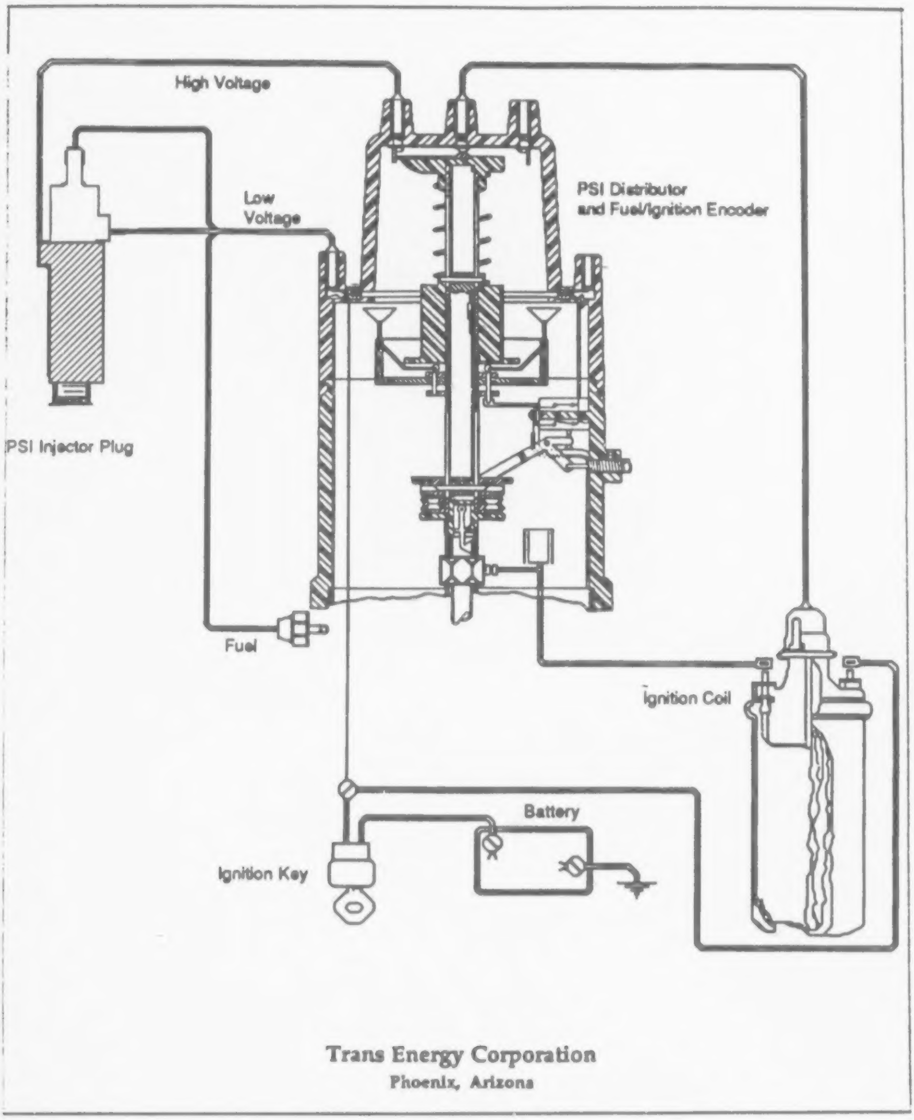
High Voltage
Low Voltage
PSI Distributor and Fuel/Ignition Encoder
PSI Injector Plug
Fuel
Ignition Coil
Battery
Ignition Key
Trans Energy Corporation
Phoenix, Arizona

Figure 1. - Precision Spark Injection System Schematic

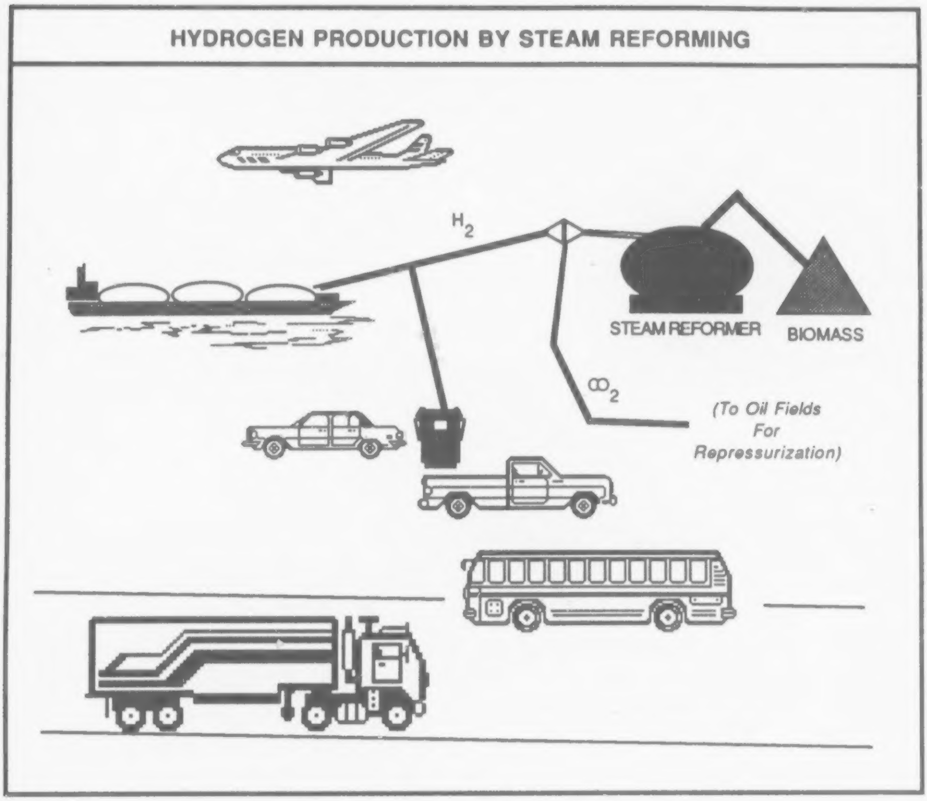
HYDROGEN PRODUCTION BY STEAM REFORMING
H_2
STEAM REFORMER
BIOMASS
CO_2
(To Oil Fields
For
Repressurization)

Figure 2. - Hydrogen Production From Biomass Using Steam Reforming

TECHNICAL ALTERNATIVES ALLOWING CONTINUED USE OF FOSSIL FUELS

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Abstract

Particulate traps, catalytic mufflers, on-board producer-gas generators, hydrogen from fossil fuels, carbon dioxide scrubbers, and hydrogen-enriched fossil fuels are technical alternatives that may be considered for allowing continued use of fossil fuels. In order to minimize the cost associated with the adoption of such alternatives, commensurate improvements in fuel tolerance, power density, range, and fuel economy are needed.

Such improvements are possible by utilizing the Precision Spark Injection (PSI) technology, which produces a stratified-charge combustion following positive ignition by plasma discharge. Fuel is injected into unthrottled air masses within closed combustion chambers. Ignition occurs within fuel-rich zones that produce high flame speeds within excess-air envelopes. Complete combustion, development of full power ratings, and significant reductions in carbon monoxide, unburned hydrocarbons, and oxides of nitrogen characterize PSI system operation, even when using high carbon-ratio fuels like gasoline. Diesel and spark-ignition engines that have been modified to utilize PSI technology are able to burn efficiently fuel alcohols, diesel fuel, gasoline, natural and L-P gases, and hydrogen interchangeably.

Air quality would be greatly improved by equipping present engine populations with PSI systems so that fuel selections such as fuel alcohols, natural gas, and hydrogen could be used to produce uninterrupted commerce, industrial production, and general travel. Depending on the fuel used, the PSI system will be able to increase the thermal efficiency of Diesel engines by up to 10 percent and carbureted engines by 20 to 50 percent. As a result, the PSI system is expected to amortize its costs in a matter of months in many applications.

1. INTRODUCTION

The industrial revolution has been fueled by fossil reserves. Marvelous technological progress and development of improved living standards have been possible because of vast fossil reserves of coal, oil, and natural gas. Exponential increases in the world population have been encouraged by exploitation of fossil fuel resources. Some 5.2 billion persons are supported by a world economy that burns fossil energy reserves equivalent to 60 million barrels of oil each day.

It has become apparent that human activities are altering the chemical composition of the atmosphere. In spite of recent progress in production of cleaner cars, air pollution-continues to threaten the environment. Americans dumped 7 percent more carbon dioxide and hydrocarbon particulates into the atmosphere in 1989 than in any previous year. Similar increases occurred throughout the world. Atmospheric levels of carbon dioxide are 25 percent higher than at any previous time during the last 160,000 years. Smog from unburned hydrocarbons shrouds our cities.

2. REDUCTION OF SMOG, UNBURNED HYDROCARBONS, CARBON MONOXIDE, AND PARTICULATES

Four alternatives are suggested by this paper for continued use of fossil fuels until renewable supplies of hydrogen are available:

1. Improve the efficiencies of vehicular propulsion and emission control devices. Examples are hybrid propulsion systems; reducing air resistance by streamlining; regenerative techniques to recover braking energy; reduced curb weight; and particle trap exhaust systems in addition to catalytic mufflers.

2. Use conventional fossil fuels such as coal, natural gas, and oil to produce hydrogen for vehicular use. Return the CO_2 to the oil field.

3. Use fuels with higher hydrogen-to-carbon ratios than current selections of gasoline and diesel fuel. Examples are liquid-petroleum gases such as butane, propane, and ethane; natural gas (either compressed or liquified); and oxygenated fuels such as ethanol or methanol.

4. Generate hydrogen on-board the vehicle using waste heat from the engine. Examples are the thermal dissociation of methanol and the production of hydrogen from a hydrocarbon fuel and an oxygen donor.

Three out of four suggestions are based on increasing the role of hydrogen in combustion chemistry. This approach is not new. By 1800, air pollution by unburned particulates from coal, peat, and wood fires seriously threatened the health of city dwellers. Black lung diseases were common in housekeepers as well as in coal miners.

William Murdock, a young Scotsman employed by the partnership of James Watt and Matthew Boulton, developed apparatus for making a clean-burning mixture of gases based on hydrogen. Called "town gas", it was first used to light Boulton's Soho works in 1803. [1]

After considerable improvement, which was supported by income from leasing James Watt's steam engines to mines, the new gas-works system was used for street lighting in London in 1810. Town gas was produced by the endothermic "water gas" reaction between water and coal to produce hydrogen and carbon monoxide:

$$(1) \quad H_2O + C \longrightarrow H_2 + CO$$

By 1830, Paris, Boston, and New York had installed "gas works" to make town gas from coal. Within the next thirty years, town gas was lighting streets, homes, offices, and factories in more than 400 U.S. communities. Boulton's faith in Watt's engine invention resulted in the launching of engines and underground distribution of town gas to energize the industrial revolution. Burning town gas solved the problems of air pollution due to particulates and unburned hydrocarbons. Ash and particulates were consolidated as a non-hazardous slag for disposal at the gas works. Town gas was the clean answer to air pollution in the 1800's.

The water gas reaction (Equation 2 on the next page) could be employed on a large scale to supply hydrogen for the transportation sector from virtually any fossil fuel and water. Separation of carbon monoxide could be accomplished as hydrogen is processed for storage as a cryogenic liquid, compressed gas, or as a hydride.

$$(2) \quad H_xC_y + y\,H_2O + HEAT \longrightarrow y\,CO + (y + 0.5x)\,H_2$$

After large-scale production and separation of hydrogen using coal, oil, or natural gas, the carbon monoxide could be further processed for uses that prevent carbon contributions to the atmosphere. An example is to use the carbon monoxide as a fuel value for the endothermic reaction and to use carbon dioxide that results to repressurize depleted oil and gas fields for continued production. This could make the cost of adopting hydrogen a negative cost. "Down-hole" carbon dioxide is valuable.

It is estimated that about 50 percent of the oil and gas often remains unrecovered at the point that an oil field is considered depleted. This is because of the loss of sufficient natural drive pressure to deliver petroleum values to producing wells. Repressurizing with carbon dioxide or nitrogen has proven useful in extending the life of oil fields. Carbon dioxide and nitrogen could be produced by the combustion of carbon monoxide in air. The following equations provide an approximate accounting of the process for producing oil-field drive gases from carbon monoxide.

$$(3) \quad CO + 0.5\,\underbrace{O_2 + 2N_2}_{AIR} \longrightarrow CO_2 + 2N_2$$

(4) *ONE VOLUME CO YIELDS THREE VOLUMES DRIVE GAS*

Use of hydrogen as a motor vehicle fuel is practical. By 1940, Rudolph Erren had converted over 1,000 vehicles to hydrogen operation or to the use of hydrogen to improve the efficiency of gasoline operation. [2]

Some of the combustion characteristics of hydrogen are particularly useful for improving the thermal efficiency of internal combustion engines. Table 1 compares hydrogen with several conventional hydrocarbon fuels. The most noteworthy properties of hydrogen combustion are high flame speed, a wide range of flame-supporting mixtures, and reduced radiation characteristics compared to carbon-based fuels. In addition, most hydrocarbon fuels having a higher hydrogen-to-carbon ratio than diesel fuel require spark ignition.

An alternative that could provide for retrofitting significant portions of the world's existing automotive fleets is hydrogen production by on-board reacting of hydrocarbons with an oxygen donor or by dissociation of an oxygenated fuel such as methanol. [3, 4, 5] Examples of suitable hydrocarbons, in descending order of potential carbon dioxide contribution, are diesel fuel, gasoline, L-P gases, and natural gas. If water is chosen as the oxygen donor for on-board production of hydrogen from hydrocarbons, the general reaction is the same as provided in the endothermic reaction of Equation 2. If "neat" methanol is chosen, the endothermic reaction is as follows:

$$(5) \quad CH_3OH + HEAT \longrightarrow 2\,H_2 + CO$$

Another possibility is to use wet methanol in the endothermic reaction to produce hydrogen and carbon dioxide:

$$(6) \quad CH_3OH + H_2O + HEAT \longrightarrow 3\,H_2 + CO_2$$

In order to minimize the cost impact due to adoption of neat hydrogen or on-board reactors that produce hydrogen, improvements in fuel tolerance, power production, range, and fuel economy are needed. Such improvements are possible by utilizing the unique combustion characteristics of hydrogen with a new technology for directly injecting and spark-igniting hydrogen or hydrogen-characterized fuels.

3. THE PRECISION SPARK INJECTION (PSI) SYSTEM

Called *Precision Spark Injection (PSI) Technology*, this system produces stratified-charge combustion following positive ignition by plasma discharge. Fuel is injected into unthrottled air masses within closed combustion chambers. Ignition occurs within fuel-rich zones that produce high flame speeds within excess-air envelopes. PSI system operation is characterized by complete combustion, development of full power ratings, and significant reductions in exhaust emissions of carbon monoxide, unburned hydrocarbons, and oxides of nitrogen. The PSI system can be retrofit onto most existing engines with a minimum of modification or downtime.

Diesel and spark-ignition engines that have been modified to utilize PSI technology are able to burn efficiently fuel alcohols, diesel fuel, gasoline, natural and L-P gases, and hydrogen interchangeably. Air quality would be greatly improved by equipping present engine populations with PSI systems so that fuel selections such as fuel alcohols, natural gas, and hydrogen could be used to produce uninterrupted commerce, industrial production, and general travel. Adoption of PSI Technology would greatly reduce fuel costs and pollution from the world's present population of 400 million vehicles. Futhermore, this solution could be effective long before new car modifications would be significant. (The rate of new vehicle dilution of the existing population of cars and trucks is less than 10% per year.)

Depending upon the fuel used, the PSI system will be able to increase the thermal efficiency of Diesel engines by up to 10 percent and carbureted engines by 20 to 50 percent. As a result, the PSI system is expected to amortize its cost in a matter of months in many applications.

4. HOW THE PSI SYSTEM WORKS

The PSI system pressure-injects engine fuel directly into an engine's combustion chambers and simultaneously ignites it with an electronically-timed spark. The engine receives the fullest possible measure of unthrottled air on the intake cycle, with the result that higher compression and power-cycle pressures are developed. The fuel is injected through a passage in the center of the PSI spark injector. As the fuel leaves the end of the spark injector, it enters the air-filled cylinder, passing through a spark plasma that ignites the fuel. As the fuel enters the compression chamber, it is surrounded by air that form an envelope around the burning fuel and insulate it from the cooler metal cylinder and piston surfaces. Fuel burning progresses from a fuel-rich, high flamed-speed zone into excess air to assure complete combustion. As a result, considerably lower emissions of oxides of nitrogen are produced compared to homogeneous-charge engines.

The PSI fuel-injector/spark-ignitor is a combined fuel injector and spark plug. Figures 1 and 2 provide a detailed description of PSI system components and how the system operates. Figure 1 provides a schematic of the PSI distributor and electrical system. A diagram showing the operation of the PSI system in a typical four-stroke engine is provided in Figure 2.

With the PSI system, engine start-up is assured, even at cold temperatures, on the first combustion chamber that progresses through top-dead-center. Engine power production is not constrained by air throttling processes or carburetor physics. By insulating the burning fuel from the cylinder walls, the PSI system keeps more heat energy in the cylinder where it can be used to power the engine. By adding excess air and, therefore, more oxygen to the cylinder, the PSI system makes it possible to burn the fuel more completely, thereby reducing emissions and further increasing efficiency. In Diesel engines, spark ignition represents an improvement over compression ignition by initiating burning during injection of the fuel and avoiding the "Diesel ignition delays" associated with the evaporation and thermal-cracking of diesel fuel required in the conventional Diesel engine.

5. ENVIRONMENTAL EMISSIONS

Diesel and other hydrocarbon-fueled engines characteristically produce substantial pollutants, including unburned hydrocarbons, carbon monoxide, and oxides of nitrogen. PSI Technology, however, results in hydrocarbon fuels being burned more completely by starting in locally fuel-rich mixtures, which assures complete combustion of an overall leaner fuel-air ratio. The PSI system introduces fuel into closed combustion chambers. Highly efficient combustion is spark-initiated within fuel-rich stratified-charge zones of air and fuel. The excess and surrounding air insulates the fuel-burning process, resulting in exceptionally low exhaust emissions of carbon monoxide, unburned hydrocarbons, and oxides of nitrogen. As a result, auxiliary air pumps, catalytic mufflers, and particulate traps may be eliminated.

6. POWER PRODUCTION

Unthrottled air admission to positive displacement engines reduces internal losses of energy that are used to produce and operate against upper-cylinder vacuums. Unthrottled air admission provides additional oxygen during combustion to assure complete burning of the fuel. By igniting stratified fuel charges within locally fuel-rich conditions, fast and complete combustion is assured as the flame proceeds into excess air. Heat transfer from stratified fuel combustion to surrounding excess air prevents much of the heat loss to combustion chamber surfaces.

In summary, increased air intake and stratified-charge combustion allows increased power production by virtue of the following:

a. *VACUUM LOSSES ELIMINATED:* Engine power is delivered to the output shaft rather than being wasted in production of intake vacuum.

b. *BETTER BURNING:* Greater air charges support faster and more complete combustion.

c. *LESS HEAT LOSS:* Stratified-charge fuel combustion reduces heat losses to combustion chamber surfaces. More heat is converted into work as heat losses to the combustion chamber surfaces are reduced.

d. *LATER IGNITION AND FASTER COMBUSTION:* Fuel-rich, stratified-charge combustion of fuel within excess air increases combustion rates and allows later ignition practices. This reduces back-work losses characteristic of homogeneous-charge ignition during compression.

7. MULTIPLE FUEL CAPABILITY

One of the more important features of the PSI system is its ability to allow Diesel and spark-ignited engines to burn efficiently a wide range of liquid or gaseous fuels, including fuel alcohols, natural gas, and hydrogen. The multiple-fuel capability of PSI-equipped engines results from the following:

a. Direct cylinder fuel injection through the spark gap;

b. Electronic metering of fuel;

c. An electronically-adjusted injection and ignition algorithm with respect to engine speed and load that is tailored to the combustion chamber and the fuel being burned.

When the fuel enters the cylinder, it is atomized and ignited simultaneously. The timing of the engine is set to provide maximum efficiency by a proprietary "fuel management map" that controls flame speed, fuel/air ratio, and timing. This fuel map is an electro-mechanical and electronic programming system located within the fuel management unit. The PSI system may be designed to have several fuel maps, each map engineered to provide maximum efficiency when burning a specific fuel. Transition between fuels is made by switching from one fuel map to another.

Table I compares a variety of alternative candidates for future fuel selections, and Table II compares the combustion characteristics of some popular fuels or fuel feedstocks. Internal combustion engines generally discard about two units of waste heat per unit of shaft energy. Reacting water with hydrocarbon fuels, as illustrated in Equation 2 above, allows waste heat from engines to be thermochemically regenerated. This results in increased thermal efficiency, vehicle range, and power production.

The "Products of Combustion" columns of Table I show that considerably larger amounts of combustion products are available from wet fuels. Thermochemical regeneration of wet fuels produces hydrogen and carbon monoxide, resulting in greater heat release with higher flame speeds than the feedstock fuel and greater volumes of combustion products for expansion during the power cycle.

Recovering waste heat in endothermic "water gas" reactions provides greater combustion heat release from the combustion of hydrogen and carbon monoxide than the original hydrocarbon fuel would provide. This benefit, along with the benefits of unthrottled air and late ignition timing, provides vehicle range improvements, reduced pollution, and increased engine life. Fuel economy improvements of 50 % over conventional homogeneous-charge engine regimes are offered by the PSI Technology.

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3. B. Breshears, H. Cotrill, and J. Rupe, "Partial Hydrogen Injection Into Internal Combustion Engines Effect on Emissions and Fuel Economy", *Project Briefing - Jet Propulsion Laboratory*, California Institute of Technology, Pasadena, CA, (1974).

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TABLES

TABLE I: FUEL COMBUSTION PRODUCTS

FUEL	HEAT VALUE PER POUND		STOICHIOMETRIC AIR-FUEL RATIO	PRODUCTS OF COMBUSTION PER POUND OF FUEL		
	High	*Low*	*(Lbs. Air/Lb. Fuel)*	*Carbon Dioxide*	*Water*	*Nitrogen*
Octane	20,529	19,029	15.11	3.08	1.42	11.60
Hydrogen	61,031	51,593	34.50	---	9.00	26.50
Methane	23,890	21,518	17.21	2.75	2.25	13.22
Benzene	18,188	17,466	13.26	3.38	0.69	10.18
Butane	21,316	19,679	15.44	3.03	1.55	11.86
Propane	21,670	19,944	15.65	3.00	1.64	12.02
Methanol	9,758	7,658	6.46	1.37	1.13	4.96
Ethanol	12,770	9,620	8.99	1.91	1.17	6.90
Butanol	16,919	15,282	11.19	2.38	1.22	8.59
80% Methanol *	7,822	6,139	6.70	1.37	1.38	4.96
80% Ethanol **	10,615	7,996	9.24	1.91	1.42	6.90
80% Butanol ***	13,529	12,220	11.44	2.38	1.47	8.59

* 160-Proof Alcohol: $CH_3OH + .44\ H_2O$

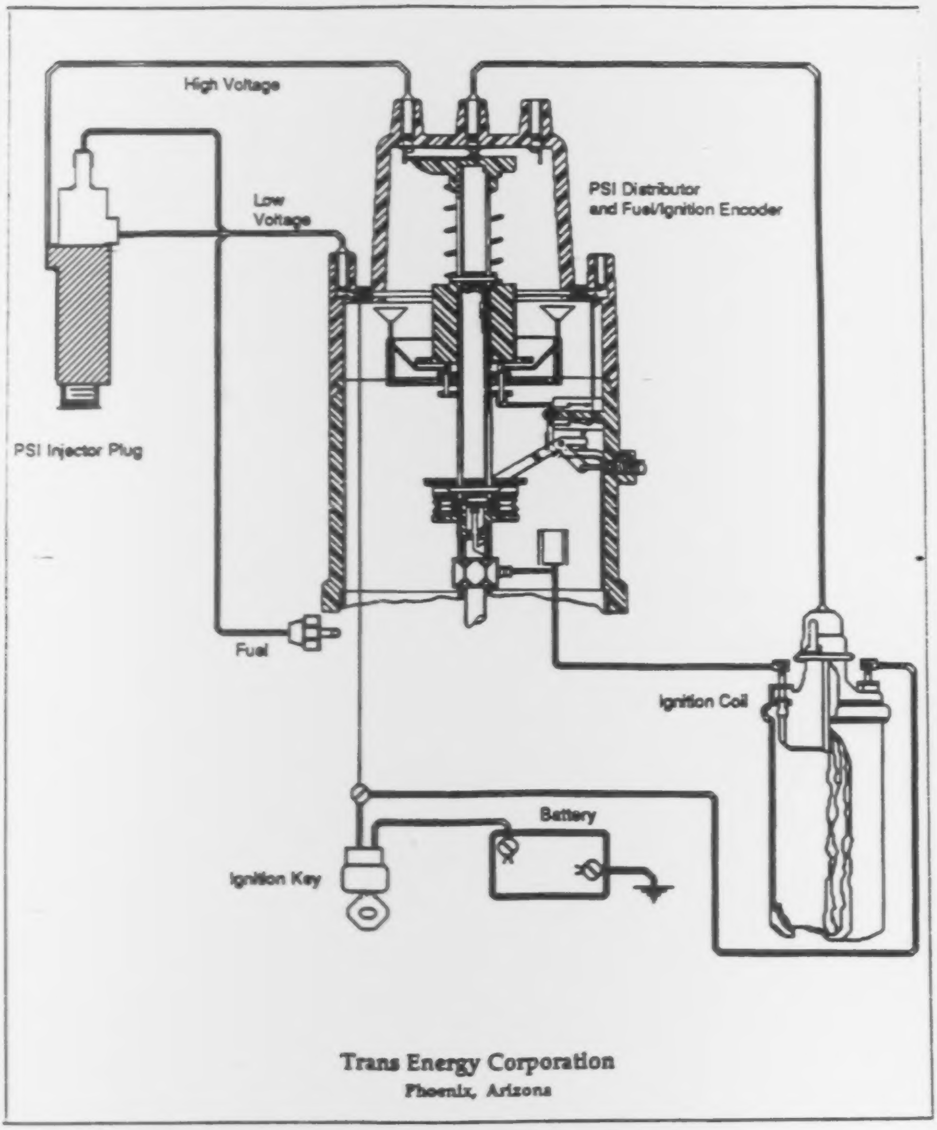
** 160-Proof Alcohol: $C_2H_5OH + .63\ H_2O$

*** 160-Proof Alcohol: $C_4H_9OH + 1.03\ H_2O$

TABLE II: FUEL COMBUSTION CHARACTERISTICS

FUEL	LIMITS OF FLAMMABILITY *		FLAME SPEED	HEAT OF COMBUSTION
	LOWER (Vol. %)	UPPER (Vol. %)	(Ft./sec.)	(BTU/lb)
Hydrogen	4.00	74.20	30,200	51,623
Carbon Monoxide	12.50	74.00		4,347
Methane	5.00	15.00	4,025	21,520
Ethane	3.00	12.50	4,040	20,432
Propane	2.12	9.35	4,050	19,944
Butane	1.86	8.41	4,060	19,680
Hexane	1.18	7.40	4,200	19,430
Ethylene	2.75	28.60	4,275	20,295
Propylene	2.00	11.10		19,691
Acetylene	2.50	80.00		20,776
Benzene	1.40	7.10	4,150	17,480
Methanol	6.72	36.50		9,078
Ethanol	3.28	18.95		11,929
Acetone	2.55	12.80	3,820	

* At 1 Atmosphere and Room Temperature


High Voltage
Low Voltage
PSI Distributor and Fuel/Ignition Encoder
PSI Injector Plug
Fuel
Ignition Coil
Battery
Ignition Key

Trans Energy Corporation
Phoenix, Arizona

Figure 1. - Precision Spark Injection System Schematic

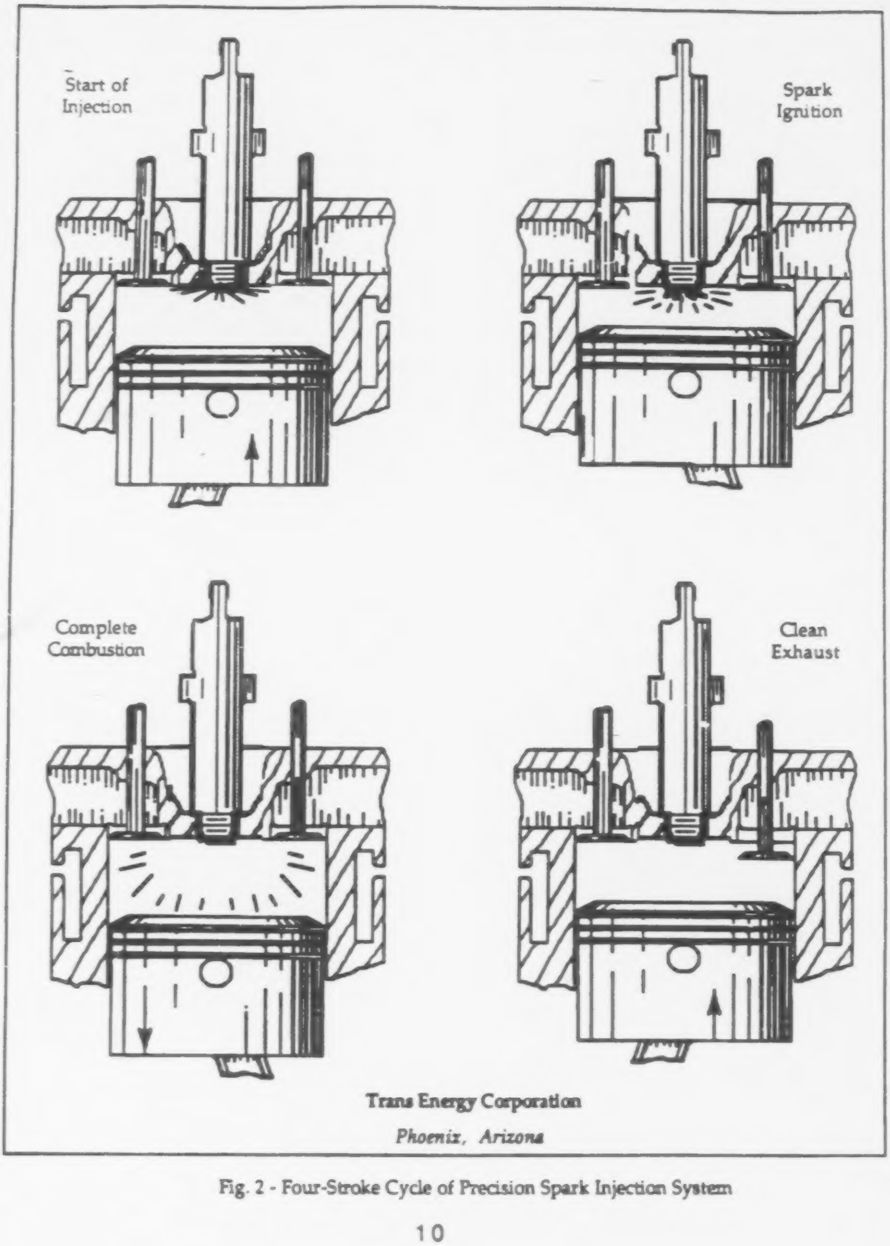

Start of Injection
Spark Ignition
Complete Combustion
Clean Exhaust
Trans Energy Corporation
Phoenix, Arizona

Fig. 2 - Four-Stroke Cycle of Precision Spark Injection System

Senator **Bingaman**. Thank you very much.

I appreciate all the testimony. Let me just ask a few questions here. We are already at noon, and I do not want to hold folks very long. But let me just ask you a few questions before we adjourn.

Let me ask Colleen and Heidi first. I appreciate them being here, and they were the first two witnesses in this panel. Could you just tell us a little more about your organization that you are part of, the Students for Environmental Education, as to what you do and how you function? I am very impressed with the substance of what you talked about in your statement. I would be interested in getting a little more information now as to what your mission is, and how you go about it.

Ms. **Fordyce**. Students for Environmental Education was founded on April 19th of this year. Our main goal is to get high school ambassadors into middle and elementary schools to teach the younger kids about the environment and different issues about the environment that are very important at the time. We would like to keep the issues very current, and then keep the kids very interested in what we have to say. I think probably that we would be better presenters because younger kids tend to look up to high school kids as the big guys.

There are approximately five different chapters in five different high schools in Albuquerque, Bernalillo, and Los Lunas. We are growing very quickly. We also participate actively in our communities. Each school has its own particular issues and interests. Highland High School, for example, has a recycling program in our school to recycle paper, and we are trying to spread that throughout the community. We also take on projects like landscaping our school and trying to get students at Highland environmentally aware. It is pretty much the same process in all the other schools.

Senator **Bingaman**. Heidi, did you have anything to add to that?

Ms. **Harris**. SEE is doing so much right now. It is amazing. We are not quite set up. We are still really in our infancy, and it is really amazing that people still are so impressed by us because we really have not done anything. We are preparing, though, and we are going to be doing some things. We want to be the representatives of our future and our children and everyone. Basically we want to say that even though we do not have very much say because we cannot vote yet, and because we really do not have very much money yet, we do see and we are going to be affected by what you do today and what you do tomorrow. That is what we are here for, is to make sure that we are aware of what you guys are doing and what the adults are doing, because we want to be prepared to take over. That is what SEE is.

Senator **Bingaman**. Thank you for being here, and thank you for the excellent statement. I do think it is very impressive the initiative that you are showing. You are getting into these issues, and I am very pleased that we have so many students around the city and around the State who are taking a real active part.

Dr. Butler, let me ask you about the manufacturing technology initiative that we had testimony on before that the Department of Energy has going with the private sector. Are you involved in that? What is your view of that? Is it an important initiative? What should be done differently with regard to it?

Dr. **Butler**. My company is not specifically involved, but the companies in our industry are. They are very excited about it. It involves taking the photovoltaic technology from the laboratory, basically, where you make square inches to where you can produce square miles. The major hurtle for their introduction for that technology is to get the cost down by increasing the ability to manufacture at production rates. So that is a major barrier, and the industry is very excited about breaking that barrier and lowering the price of the technology so that it can be used more widely in the country.

The other initiatives, the solar thermal initiative, is slightly different in that the technology is ready but large power plants need to be built in order to reduce the risk, and utilities and industry are sharing that risk together with the Department of Energy so that the technology can be transferred from Sandia labs to the industry. I think the industry has been a major supporter of these initiatives through the Office of Management and Budget and through the administration, and we have been consulted and feel comfortable that the department is working diligently to involve industry in these initiatives.

Since we are putting our money into these, many of them are cost shared at 40 and 50 percent by industry. We are also getting a say in what the structure is, and how the technology will actually be implemented. So there is a lot of money coming from the industry side, and we think that is also exciting. It lowers the bill for the taxpayers, and the beneficiaries are paying for part of the technology transfer.

Senator **Bingaman**. Let me ask Mr. Hanson. You are suggesting that the geothermal tax credit that was once again renewed for a year needs to be permanent. What type of concrete results would occur if we did that? I mean Congress obviously is on a year-to-year budgeting cycle, and we have the Gramm-Rudman process and all the rest of the overlays which put pressure on Congress to sort of keep their powder dry on where we are going to give up tax revenues in the future. I think that is one of the reasons why this thing keeps getting renewed on a yearly basis. What concrete change would you expect to occur if we did make that permanent?

Mr. **Hanson**. Can I refer this to my tax specialist?

Senator Bingaman. Yes, that would be great.

Mr. **Hanson**. Mike Wright from the University of Utah Research Institute.

Senator **Bingaman**. Your name is Mike Rider?

Mr. **Wright**. Wright, W-r-i-g-h-t.

Senator **Bingaman**. Wright.

Mr. **Wright**. I am certainly no tax expert. I am more of a geologist. What I would expect is an increase in the rate at which geothermal energy is being put on line. As you probably know, the majority of the geothermal resources are on public land, and it is then typical for the Federal Government to derive a royalty from geothermal production. And I think Jim mentioned that the current royalties are about $20 million from geothermal production on public lands; and obviously if you increase that substantially, you increase the royalties. So I really think the net benefit would be more environmentally advantageous geothermal energy on line, and I have an impression, kind of off the top of my head, that there would not be an adverse economic impact on Federal Government from that.

Senator **Bingaman**. Jan, just let me ask what you think the right time frame would be for a responsible energy policy? If the department and the President proposed to the Congress an energy strategy here in the next 6 months, should we look at what can be accomplished between now and 1995 in terms of the percentage of our energy coming from renewable resources? Is that a reasonable time frame? What do you suggest? You were suggesting that the year 2030 is so far away that it makes no sense, and I agree with that. Gene is famous for saying in the long run we are all dead, and that is what I think of when I hear 2030. Tell me what you would want to see that energy strategy suggest in terms of a time frame?

Mr. **Hartke**. I first think that the President has to come out with a national purpose; that we actually want to make the transition as quickly as possible. That statement alone, that we want to have an efficient, renewable technology system that runs the energy structure in this country, is the first thing that needs to be done. He has not even, to my knowledge, ever even said that he wants that. So, first, I think we have to have him make that statement, that he wants it any time within the next millennium.

The second comment is absolutely we have to have target dates for the achievement of different things. And I think being a New Mexican, and having lived here, and knowing the great talent that we have at the laboratories, it just seems that they are going to have to see a conversion from military weapons research and so forth. And I think there is no better challenge than to give them a task of coming up with these new kinds of efficient, renewable technologies. I think that that technology transfer then can be spread out to the businesses of New Mexico.

So I think what we need to have is target dates. Let me give you one example. A paper done by Joan Ogden, a plant physicist out at Princeton, in her book called Solar Hydrogen: Moving Beyond Fossil Fuels has suggested a phase-in of hydrogen vehicles. She suggested in her book that you need a nice sunny location and suggested maybe Phoenix would be good. For some reason, those of you in the audience will be pleased to know, I thought maybe Albuquerque would be good; and then it seemed to me that New Mexico could become a State leader within the United States in terms of trying to get these vehicles to be running on hydrogen here in Albuquerque. A demonstrated project, that Joan Ogden suggests, I think could excite the American public to let them even know that there is an alternative. That these things are not dreamy, fuzzy ideas out there, but they are right here and now. While there may be cost problems, or while there may be volatility of fuel issues and forth, while there may be other kinds of technological things we have to get over, that is why we need to call on the talent and genius of this State.

She suggests that by 1995 that we have a 30,000-vehicle fleet that would be running here in Albuquerque. I think that that vehicle fleet right here, whether it is 30,000 or 10,000 or 100,000 or whatever, would excite Americans and would excite the world.

Today, I just want to say one more time, because it is so evident to me on what is happening on this, when Timothy Worth, Senator Worth, from Colorado went and drove around the first hydrogen vehicle, was it a Chrysler? No. Was it a Ford? No. Was it a GM product? No. It was a Mercedes-Benz. There is a picture up in the back from the American Automobile Association about a hydrogen car. What kind of car is it? It is a BMW.

The Germans are spending $50 million of public money, and perhaps as much as 10 times that in private money in trying to fund the hydrogen research, trying to find out whether a gen set or what kind of a solar apparatus would be best able to produce the energy and to make the hydrogen.

Then they are trying to develop hydrogen infrastructure so that they can have a complete vertical operation, so that when what I call the environmental override comes down, and somebody says, listen, we have a global warming problem, which is what most of the scientists in the world are saying today that could become the greatest threat to the future of our children and the 21st century, we have to have clean running machines and clean factories, the Germans are prepared to take that economic and environmental leadership. The Japanese are now putting $21 million a year into hydrogen research. We are putting less than $3 million a year into hydrogen research.

Just a couple of other examples. I heard them talk about PV technology here in the United States and what the labs are doing, and I am sure they are doing a great job within their budget cuts and constraints. In 1989 the United States spent $35 million for PV research; 10 percent of the support level for nuclear power; 6 percent of the support level for fossil fuels, including the coal, the thing called Technology Program. The Bush administration budget request for photovoltaic research in 1990, which has made tremendous strides forward, was 29 percent less than the appropriated budget for 1989, while the administration sought a 71-percent increase in funding for clean coal technologies.

The Germans and Japanese with smaller economies spent $60 million and $45 million respectfully for PV research. We are getting our pants beat off of us in world competition for the future. And I just think from an economic standpoint and from an environmental standpoint, my perspective is this: America should lead the world on these issues as a good example, and the power of good example is everything, then we will have the product that the world wants; and we will be able to once again be a power that Americans are proud of.

Within that context you are going to have to ask yourself, which State is going to take the lead now on solar? Which State is going to take the lead on wind? Which State is going take the lead on geothermal? Which State is going to take the lead on PV? Which State is going to take the lead on hydrogen? Right now I can tell that there are other States looking around very, very hard. This man here comes from Arizona, from Phoenix, I believe. Is that right, Roy?

Mr. **Wright**. That is correct.

Mr. **Hartke**. They are taking a hard look at that. They just had a $100,000 hydrogen exhibit to try to bring out what is possible;

that these technologies are on board right now, and we need not be dependent upon dirty technologies that are killing the future for our children.

So I think that if we here in New Mexico could within the context of the President's National Energy Policy say that New Mexico has as its goal to create in 1992, a target date of some sort—I do not think, Jeff, that I am prepared to be able to tell you what I think your best experts here in town can tell you in this State. But I am prepared to say that I know one thing, you need a target date, and you need to be able to show a steady progress. It needs to be compressed within a truly urgent situation, which is what it is. And then I think New Mexico can be the leader within the United States, and the United States the leader within the world.

Senator BINGAMAN. Thank you very much.

Mr. McAlister, let me just ask you what do you think realistically it would cost to have a demonstration project established someplace in the country, Phoenix, Albuquerque, whatever, that would demonstrate for all of to us to see that solar hydrogen, as you refer to it, is a viable fuel that can be used to power fleet vehicles?

Mr. MCALISTER. It actually would be a program that would save money. One way to instrument the occasion of demonstrating hydrogen would be to derive hydrogen wastes, such as sewerage and municipal wastes. Every year this Nation has wastes to the extent that if we would derive hydrogen by hydrolysis or by processing we would have about 20 percent of our petroleum energy replaced by hydrogen, and the carbon left over would be more carbon than from mining of coal every year. It also would be a program that would save money in the environmental impact and the cost of that impact.

In dollars what we recommend is the application of two technologies. First, as I have mentioned, the derivation of hydrogen from wastes, and the use of what is leftover as a heat source in the carbon industry, and we recommend an accelerated use of photovoltaics for electrolysis along with concentrated solar energy or heat engines or solar gen sets or solar application sets as a replacement for fossil fuels. The dollars that go to either of those applications depend upon where they are located, because they solar-energy driven processes.

If the State of New Mexico would devote ultimately something less than 5 percent of its land mass to collect solar energy and conversion to hydrogen, this would replace all of the now used fossil fuels in the transportation system in American and have some left over. The meaning of that statement is that New Mexico is a very energy-rich State that is wasting energy.

Here is another extension of the thought that if we convert wastes into products, we would have a very good chance, a high probability, of suiting infrastructure that we have in a way it brings prosperity without pollution.

Senator BINGAMAN. Thank you very much.

We can go on for a long period here. There a lot of other questions that occurred to me, but we have run over our time. I think we probably better conclude the hearing at this point; and if I have additional questions, I will probably be in touch with each of you to ask those individually.

I want to thank all the witnesses for the excellent testimony. We have a much clearer understanding of what needs to be done in this area.

I want to thank BDM for allowing us the use of this great facility. I hope that we are able to implement a National Energy Policy soon that focuses additional attention on the technologies that we have talked about here.

New Mexico I think could contribute a great deal toward this. I think we have some resources here, engineers and scientists whose talents can be put to excellent use.

Before I adjourn, let me just remind the folks that we will keep the hearing record open for a 2-week period; and if people would like to submit testimony, they can contact my office here or in Washington. I want to thank all those who sat through the hearing. I think it has been useful. I appreciate your interest. Thank you all.

We will conclude the hearing at this point.

[Whereupon, at 12:15 p.m., the hearing adjourned.]

APPENDIX

Additional Material Submitted for the Record

Gentlemen:

My name is Dr. Christopher B. Wallace. Presently, I am a senior scientist with BDM International but I am here today as a member of the American Physical Society and an interested citizen to make a statement on certain aspects of the national program in fusion energy. I believe these remarks to be timely since the FPAC committee, established by Admiral Watkins, submitted its final report in September.

Inertial Confinement Fusion:

I suspect there is a community concensus that construction of the Laboratory Microfusion Facility is a reasonable next step. The decisions to be made include what driver technology should be used and where should the facility be located. Regarding the first judgment, there are four driver technologies being pursued:

- Glass Lasers - LLNL is the lead laboratory. The NOVA facility has and will continue to produce useful data for the forseeable future. Nevertheless, the technology scales unfavorably to the LMF from a cost and engineering risk standpoint because glass laser energy efficiencies are too low.
- Excimer Lasers - LANL is the lead laboratory. Similar efficiency problems plague this driver technology. Consequently, the technology also scales unfavorably to an LMF facility.
- Light Ion Beam - SNL is the lead laboratory. Driver technology is efficient and the engineering scaling risk is minimal. Don Cook and the PBFA II staff will find out shortly whether nature will allow beam focusing to useful intensities. If this work is successful then this is the best existing driver candidate for the LMF.
- Heavy Ion Beam - When the accelerator technology is developed this will be the best driver choice for the LMF. If the light ion beam focusing

> experiments at SNL are unsuccessful, then developing this technology becomes imperative. LBL and LLNL are leading the design efforts but they have limited experience with intense beam transport systems and the associated pulse power technology.

Whether or not the Sandia experiments on light ion beam focusing are successful, the people of the United States have significant investments in pulse power hardware and personnel expertise in New Mexico, particularly in Albuquerque. Significant technical expertise in some aspects of heavy ion beam physics, however, resides in California. Some people believe that this is sufficient to justify building the LMF in the bay area. I disagree. Rather than duplicate the investment made in New Mexico by siting the LMF in California, it makes more sense to establish an organization similar to CERN for the LMF and site the facility south of Albuquerque on the Sandia reservation. This will maximize the return on existing government expenditures and minimize the relocation of personnel necessary for construction and operation of the LMF. Before moving on to comment on the magnetic confinement program, let me conclude this section of my remarks by noting that some members of the FPAC I have talked to believe it will be politically difficult to site the LMF in the bay area due to local political opposition.

Magnetic Confinement Fusion:

Let me begin my remarks on the magnetic confinement fusion effort by noting that within the next 18 months the TFTR and JET tokamaks will demonstrate scientific breakeven. This occurence represents both an end and a beginning. We will have reached a destination that has required 40 years to reach and, with time, will be recognized as a major milestone in the scientific history of the twentieth century. The achievement can also represent a beginning as we begin to search for practical implementations of the technology.

FPAC member Linn Draper has been an acquaintance of mine for the past ten years. He has consistently made the point that no utility will, in the forseeable future, invest in the construction of GWe power stations. Utilities will add capacity in 250 - 500 MWe units. DOE fusion plant studies performed at intervals over the past ten years based on design extrapolations from present tokamaks will not scale to lower power and, I suspect, will cost too much relative to the financing public utilities will be able to risk.

How, then do we implement the technology ? Alternative concepts, as an item in the fusion program budget, are a small fraction of the overall program at present with no centralized advocacy within the Office of Fusion Energy. Consequently, there are some small deserving programs with the potential for large payoff that have funding difficulties. Let me mention two by way of example. There are programs at LANL and the NRL working on dense Z pinch technology. The potential military and civilian payoff is, I believe, substantial, however, people I know working in both programs have indicated that obtaining adequate funding in any given budget year is problematic and a difficult exercise. The second example concerns the compact toroid/spheromak work being undertaken at LLNL, Caltech, the Air Force Weapons Laboratory, and the University of Washington. Each of these programs is struggling to exist from one year to the next. The potential payoff here is that these devices may prove to be the modular, reasonable cost fusion systems that utilities will be able to pay for. As a general hypothesis, I suspect that the more complicated the physics is the simpler the engineering hardware becomes, hence the cost of the power system will be lower.

What should be done ? I would like to recommend that an alternative confinement concepts office be established within the DOE and perhaps located in two places, Washington DC and maybe LANL or some other location near where the alternative prorgams are sited. While these programs are able to make progress in spite of their budget situation and we don't want to discourage this movement by imposing a large bureaucracy, I believe that the establishment of such an office would permit the programs to have the advocacy they require in order to realize the potential payoffs in a timely and cost effective manner.

Ad Astra, Ltd.
Engineers and Builders of the Future

Route 1, Box 92 LL - Santa Fe, New Mexico 87501, U S A (505) 455-3484

31 October 1990

Faxed to Albuquerque Office: 766-2482

Jeff Bingaman
U. S. Senate
Washington, DC

Dear Senator Bingaman:

The purpose of this letter is to present an alternative energy technology which: is environmentally benign; will require the talents of the scientists and engineers of the national laboratories and defense complexes here in New Mexico; and benefit the peoples of the world. The technology is electric power from space. The technology was doable in the late 70's. It is even more feasible now especially if the work done by the national laboratories for SDI is taken into account. A program to provide energy from space will finally utilize the tremendous resources we have invested in the space program for the benefit of the common man.

Space, Energy and the Environment will be intertwined in the 21st century. The nation which recognizes this fact and seizes the economic opportunity in the 90's will be the dominate economic and foreign policy leader, at least for the first decade, of the 21st century. Japan, Germany and the Soviet Union ;have recognized this fact and have on-going technology development programs in the area of satellite power systems. As the provider of environmentally benign energy from space, the nation which draws upon the space based resources of greater Earth will be able to help its poor and improve the quality of life for the rural poor of the third world while providing technically demanding jobs for its citizens..

I wish to emphasize that Space, Energy and the Environment is not an alternative to the SEI but rather a rationale for implementing a program of exploration, technology development and resource utilization. I agree with former NASA historian David Compton that "Without some compelling national objective" we will not see voyages of exploration to Mars much less a return to the Moon. The exploration of space for exploration's sake is just as good of a way to destroy the capital formation capacity of a nation as defense, super colliders and welfare ~~spending~~.

A compelling rationale for a national space program rather than a NASA space program is to improve the global environment by utilizing the resources of space to provide environmentally benign energy to both the developed and developing nations. Preserving the fragile world we inhabit and providing for our children are our first responsibilities. However, if we can meet our responsibilities by pursuing our dreams into space then we have also provided our children with hope, new futures and a sustainable economy and environment. Admiral Watkins phrased it a bit differently when he stated: "To achieve economic growth in an environmentally sound fashion, we must develop energy technologies that contribute to global stewardship" If we do not take action in this decade the U.S. will not only be buying oil from the Middle East but electricity from Japan in the 21st century..

The U.S. through DOE could provide developing nations with considerably more help in building efficient and environmentally sensitive energy systems. A greater role, perhaps now than ever before, is well worth contemplating given: those nations pressing energy needs, the effect their actions have on the global environment, worldwide concern for the environment and our need to find substitute employment for the skilled technical workers being laid off by reductions in defense and SDI spending.

Congressman George Brown (D-CA), chair of the House Space Caucus, has incorporated some of my ideas in his speeches. Senator Domenici helped arrange a series of briefing to DOE, which I will be giving November 8th. If you or your staff would like I would be happy to forward a copy of the briefing to you. Please don't ask me to send it to Ed McGaffeny. Having briefed him last year in Washington on a joint effort I was involved in with Los Alamos, the University of New Mexico and industry I know his views on space and science. Seldom have I encountered such a hostile reaction as his.

Sincerely,

Raymond S. Leonard, PE
President, Ad Astra, Ltd.

suntek ENERGY MATERIALS FOR BUILDINGS THROUGH MOLECULAR DESIGN

November 21, 1990

Senate Energy & Natural Resources Committee
Attn: Subcommittee on Mineral Resources
Development and Subcommittee on Reseach
and Development
364 Dirksen Senate Office Building
US Senate
Washington, D.C. 20510

Attn: Mr. Jim Langel
Energy Committee Submission

Dear Mr. Langel:

Enclosed is some material I would like to submit for the record on a hearing in Albuquerque, New Mexico on November 1, 1990. If you need any additional information or have any questions, please do not hesitate to contact me.

Sincerely,

Day Chahroudi
Research Director

DC/cs

enclosures: An Effective Federal Renewable Energy
Policy
Citizens SUrvey of the Solar Federal
Bldgs. Project

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ENERGY MATERIALS FOR BUILDINGS THROUGH MOLECULAR DESIGN

AN EFFECTIVE FEDERAL RENEWABLE ENERGY POLICY

1. An effective government mission would be to encourage the development of renewable energy products by the private sector.

   - Products that make a profit mobilize the private sector, which in turn educates the public through advertising

   - With a few notable exceptions, government labs have not delivered much solar bang for the taxpayer's buck. Most of their solar projects would have been economic failures if they weren't technical failures. These high visibility failures have given the public the impression that "we gave solar a fair shake but it didn't work". The solar industry would now be better off if the money spent by government labs on solar energy had been spent on particle accelerators

   - DOE is a primarily nuclear establishment which has a basic conflict of interest with solar energy. It's a case of letting the rabbits guard the carrots. Squashing the nation's opportunity for energy independence under a DOE pork barrel serves the interests the oil and nuclear lobbies alone. The role of government labs should be limited to hi-tech research such as photovoltaic cells or solar hydrogen. Future government solar programs should be managed by the EPA.

   - Research is not a top priority because viable renewable energy products already exist. Building a renewable energy industry depends only on effective marketing and on accounting and tax practices which recognize the real cost of pollution to the GNP in medical costs, and due to reduced health, productivity and life expectancy. Pollution causes $7 billion dollars per year of medical expenses alone in California.

   - Federal budget allocations for renewable energy product and market development should be in inverse proportion to company size because developing new products and markets traditionally starts with small, entrepreneurial companies as product champtions.

   - Successful renewable energy entrepreneurs should form a government advisory committee to publish a "how to" book and a review of past and current government efforts

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2. A model of effective government renewable energy policy is the development of low e coatings for sealed windows which:

   - Triple the insulation value of sealed windows but are invisible
   - Payback in a few years in United States, and are free in Europe
   - Reached 75% market saturation in 7 years
   - Prevented 1/2 billion tons of pollution
   - An $8 billion glass coating factory saves as much oil as a $300 million oil drilling platform produces
   - Would save as much energy as the Alaska pipeline produces if all United States windows had it
   - NDF, ERDA, and DOE invested $1.5 million with no strings in Suntek, a small entrepreneurial company formed by the inventor of low e
   - Performance was certified and diseminated to the window industry by a government lab
   - Adopted by most large glass companies at a cost of about $300 million to them
   - Low e has reduced world energy consumption by 0.1%, a larger contribution then Sandia and Los Alamos
   - At that rate, the cost to the taxpayer for 100% renewable energy for the world is $1.5 billion
   - DOE has spent over $1 billion in solar energy, resulting in less than 1% reduction in world energy consumption
   - At the same market penetration rate as its last product, low e, Suntek's next product can reduce world energy consumption 6% by the year 2000 and 17% at market saturation

3. Since the fair and logical thing to do - taxing the sources of pollution for the cost of pollution - is politically impossible in the United States due to the strength of the oil and nuclear lobbies, which now have a several billion dollar per year free ride at the taxpayers expense, a pollution credit would simulate a free market by leveling the playing field between renewable and non-renewable energy technologies. The credit would:

   - Be proportional to the amount of pollution prevented over the lifetime of a product in the climate it is sold in, so the credit does not encourage marginal solar installations

   - Encourage capitalism and small entrepreneurs, the United States spirit. For example, oil and power companies would compete with small insulation contractors with equal opportunity

   - Minimize beauracracy - the only government tasks would be evaluating the performance of products and their sales figures

   - To avoid the problems of the last solar tax incentive, this credit would go to manufacturers and distributors of renewable energy products, not to consumers

   - The taxpayer's investment would be leveraged many times by the private sector, as happened with low e, which was leveraged 200 to one this way

CITIZENS SURVEY OF THE SOLAR IN FEDERAL BUILDINGS PROJECT

CITIZENS SURVEY OF THE "SOLAR IN FEDERAL BUILDINGS PROJECT"

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INTRODUCTION:

Anyone in the solar heating business knows that the public is very skeptical about solar energy and suspicious of people in the solar heating business. I believe this has come about because of the enormous amount of tax money spent on solar energy in the late 1970's and '80's. Because they were subsidized by the tax credits, people purchased expensive systems which produced little energy. America wasted hundreds of millions of dollars.

Along with the tax credits was the Solar in Federal Buildings Project (SFBP). Many installations were prominent displays. A huge share of them did not work and many have been torn down.

Harold Hay suggested this survey in April of 1988. People in the solar energy business need to know what the Department of Energy has left us with. Fred Morse, of the DOE, provided the list of the 700 SFBP projects. At the June 1989 ASES conference in Denver, Colorado, I announced plans for the survey and requested assistance. I promised to report on the findings at the 1990 ASES conference.

I accompanied Harold on an inspection visit of a federally funded solar heating system at a defense contractor's office building in Albuquerque, New Mexico. When we signed in Harold asked for the janitor. At first I was puzzled, but Harold explained, "My God man, that's one fellow you can be sure is giving you the straight story."

The reports in this survey have been gathered largely by telephone from project supervisors. Like Harold, I would have liked visits with janitors, but I have been pleased with the frankness of those with whom I spoke.

Along with my report, I have also included Gregg Kortman's report on Utah.

My Abstract, which follows, was judged to be "highly political" by the ASES Program Technical Review Committee, and my proposed talk considered a "personal diatribe" which "had no place in a technical meeting of this type".

I think back on the janitor telling Harold and me that the shiny concentrators on the roof (at least half a million dollars of tax payer's money) hadn't worked for years.

ABSTRACT

Citizens' Solar Survey

Approximately $20,000,000 of United States taxpayers' money was spent on about 700 solar heating and cooling projects. Do any of these projects still work? Those of us who have stayed in the solar heating and cooling business through thick and thin have seen for ourselves many failures from among these projects - ruptured lines, broken glass, tattered insulations, whole systems scrapped. Many potential customers were dissuaded from ever using solar heating or cooling by the very projects intended to persuade them!

My paper will cover several expensive installations in New Mexico (at least one of which is not a failure, but a great success) discussing in some detail what worked and what did not. I will also refer to the reports of others around the country in Utah, Florida, Arizona and Wyoming who have examined projects in their regions.

Our industry is obsessed by the the investigation of flat plate collector efficiency, solar fraction of yearly energy and many other important matters of solar economies. We must also inquire about the efficacy of large programs such as the solar heating and cooling projects. What can we learn from past experience? I expect to show that the customers spending their own money, not taxpayers' money, make better use of every dollar and take care of the investment in years to come while systems paid for by the government are often abandoned.

How can the country protect itself against such wasteful debacles? There is one simple answer - don't ever set out on them.

NEW MEXICO:

Los Alamos:

There are three installations in Los Alamos, New Mexico.

1. Atomic Museum Courtyard Cover.

Design cost:	$ 24,400
Construction cost:	165,000

This is a passive heating system which evidently consists of clerestories in a roof. Brooke Davis, the agency contact, says the system is still in place and continues to work.

2. Nuclear Waste Evaporator.

Design cost: $ 110,400
Construction cost: 891,400

This system, which has now been sold as scrap, consisted of focussing trough collectors. According to Brooke Davis, a week or two after it was installed a lightening strike blew out the controls. The group using it did not think it would be worth repairing and so it was not fixed.

3. Occupational Health Building.

Design cost: $ 32,600
Construction cost: 328,625

This system consists of evacuated tube collectors placed in front of stationary concentrators and cooled by a drainback system. The system had been operating for about two weeks in 1982 when it was discovered that nitrogen leaked out of the collectors making it expensive to shield the liquid in the tank. The cost of nitrogen was greater than the savings of energy. The system was shut down two weeks after it was started up. The system is still in place and, despite some broken collectors, the engineers are considering repairing it and using it again.

Comments of Brooke Davis explain the puzzle of the abandonment of the two projects which together cost $1,350,000. There was lots of money available to build them, but no allowance for repairs or maintenance. When Ronald Reagan was elected president investments had to be justified by their payback. Evidently repair costs were not considered justifiable.

There is another large solar heating system in Los Alamos which was built in 1977 and paid for by a special act of congress. It is not part of the Solar in Federal Buildings Project. This is an 8000 sq.ft. flat plate collector that powers both an absorption chiller for cooling and a heating system. According to Jim Hedstrom, the success of this system is owed to the parafinic oil which is very stable and able to withstand high temperatures.

Albuquerque:

The Lovelace Lab at Kirtland AFB.

Design costs: $ 56,000
Construction cost: 326,000

This is a domestic hot water system with 2600 sq. ft. of flat plate collector. It was designed by the Bridgers and

Paxton engineering firm in Albuquerque with the assistance of John Lopez, the contact person listed at the Lab. Lopez states that the system saves about $10,000 a year, considering the alternatives of No. 2 oil or propane.

When asked if it would be possible to visit the building, Lopez told this reporter that the system was not operating because of the excavation of a nearby oil tank, but would soon be running again.

Las Cruces:

NASA Office Building.

Design cost:	unknown
Construction cost:	$ 54,000

This is a passive system with approximately twenty 2' diameter, 15' high culverts filled with water placed behind glass along the south wall of the large office building. Fans moved air from this space into the building. It was used from 1981 - '83 according to Jack Brieby, but did not save any money and was therefore dismantled. The culverts have since been used in road construction.

Brieby described the system as an ill conceived eyesore. When asked to spend another $150,000 on a solar water heating system, Brieby convinced the authorities against it. Instead, floating insulators were placed on the large body of water to be heated - saving energy for a fraction of the cost.

Gallup:

Federal Building.

Design cost:	$ 29,813
Construction cost:	322,627

This is a water heater with a flat plate collector and heat exchanger with an ethylene glycol loop.

Tom Speight, the contact person at the building says that the system works fine.

Carlsbad:

This reporter was unable to reach the Department of Interior to discuss the Carlsbad solar system.

Other large government financed solar systems in New Mexico:

BDM Building, Albuquerque.

This solar system has nine rows of 7' diameter concentrators, each 120' long, which focus on photovoltaic cells cooled by liquid. It produced 37 Kw of electricity and hot water. According to Wayne Kaufman, it worked for a couple of years, but was not cost effective so it was abandoned.

PROJECTS IN OTHER STATES:

Approximately half of the 700 systems (327) list Richard Davis of the Department of the Interior as the contact person. Each of these projects cost about $3,000. These were all solar water heaters in western states.

Davis estimates that at least two thirds of the systems which were installed during the early 1980s are still operating. Davis insists that he would never do it again; that they do not save money. This reporter was very impressed by Davis' opinions and thorough knowledge of the problems of solar water heaters in the Park Department.

Davis bought all one type of solar water heater (Novan - now out of business), thereby getting a very good price. In Hawaii, where there is no freeze danger, Davis never-the-less used heat exchangers because he wanted uniformity. He reports some pump problems, few control problems and many problems with the heat exchangers because of bad water at western desert locations. He hired one contractor, a Mr. Wong from Sacramento, who ran several installation crews and became very good at installing Novan systems.

Davis said he hates to have people walk on roofs. This is almost reason enough to not use solar water heaters. He has taken many systems down because of roof problems, not performance problems.

Gainsville, Florida:

The Job Corps Building.

Design cost:	$ 42,850
Construction cost:	531,507

In September of 1989 I spoke to Tom Lane of the Energy Conservation Service of Northern Florida in Gainsville who reported that a huge solar heating and cooling system on the Job Corps Building - 4,200 evacuated tubes had been torn down in July of 1989.

Lane reported that the roofers who were repairing the roof tried to give the solar collectors away, but no one wanted them.

What went wrong? Leaking O rings.

Lane visited the site and spoke with wonder of the galvanized steel racks and stainless steel bolts which "could have held a battleship".

I spoke several times with Al Stith of the Department of Labor to learn more about the three Department of Labor projects including the $316,000 project in San Marcos, Texas and the $106,390 project in Shreveport, Louisiana. Stith finally told me that his superiors demanded a written request for information. This was sent on February 10, 1990, but there has been no answer at this time, 14 March.

United States / Canada Border:

There are about ten space heating systems installed on U.S. Customs buildings.

Construction cost: $ 40,000 / each

Harry Thomason reports that all of these space heating systems except his own Solaris trickle collector in New Hampshire have broken - most soon after installation.

Jefferson, Arkansas:

Health and Human Services Building.

Construction cost: $ 687,500

Waymond Meins reports overcoming great difficulties caused by an incompetent contractor, but finally getting this 8000 sq.ft. flat plate collector system operating. It provides both hot water and space heating. This collector system is placed on a special rack beside the building, not on the roof. Meins was not optimistic about the system saving much in energy costs.

CONCLUSIONS:

If these projects were to save energy, they are, by and large, failures.

If the SFBP was undertaken as research into the use of solar energy in Federal buildings, it is a failure because no one has yet published a report on the experiment.

ACKNOWLEDGEMENTS:

I would like to thank all those people who took the time to discuss their projects over the telephone - particularly Richard Davis and Brooke Davis.

I would also like to thank Harold Hay and Harry Thomason for their help and inspiration and Gregg Kortman for starting the action.

SOLAR IN FEDERAL BUILDINGS PROGRAM: A UTAH SURVEY

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ABSTRACT

Approximately $20,000,000 of United States taxpayers' money was spent by the Department of Energy (DOE) during the Solar in Federal Buildings Program (SFBP) on about 700 solar heating and cooling projects. At least six communities in the state of Utah participated in this program, constructing 31 projects at a total cost of $289,251. Even though this represents only about 4.4% of the projects and 1.4% of the SFBP budget, it is still important to know what was done in these projects and what their condition is today. This paper presents an overview of what was done on each of the 31 SFBP projects accomplished in Utah and reports on their current status. It presents the cost of each project and, where possible, an assessment of the savings or loss of each project over their lifetimes. This information is used to determine which of the projects was a success.

1. INTRODUCTION

This project began with a request from Steve Baer (Zomeworks) for volunteers to look at the SFBP projects built in the early 1980's. He provided a DOE computer printout of projects accomplished in Utah. With this list, a letter was drafted and sent to the Chambers of Commerce in the communities where the projects were built. Each Chamber of Commerce forwarded their letter to the city or county engineering staff and they attempted to provide an answer. This was effective in only one of the six communities contacted because local communities were not involved in the federal projects so they could not emphatically identify them. The one project that was identified through this letter was the Indian Health Service Center at Fort Duchesne.

A second attempt was made to identify and locate the projects by making telephone contact with the agents responsible for each project. The necessary information to do this was also on the DOE computer printout. This proved ineffective because office personnel at the applicable agencies were not able to identify (with certainty) the exact projects from the information given on the DOE printout. This process quickly became a chain of telephone transfers that clearly was going to lead no where.

Finally, the third attempt to learn the exact location of the projects was successful. A letter was sent to Clifton L. Carwile (Acting Director, Office of Solar Heat Technologies Conservation and Renewable Energy) asking for exact names and addresses for the SFBP projects in Utah. He forwarded this letter to O.R. Hillig (Solar In Federal Buildings Program, Energy Technology Engineering Center) who quickly responded to the request and provided the needed information to exactly identify each project. With this information, each project site was contacted by telephone, system maintenance personnel were interviewed, and the current condition of each project was determined.

2. METHODOLOGY

Mr. Hillig's letter indicated that the six projects in Utah consisted of four locations where DHW systems were installed on several buildings in each of four state parks and the remaining two projects were located at the Ogden City Federal Building, for DHW, and at the Indian Health Service Center, for both DHW and space heating. It was a simple matter to call each organization and talk with resident maintenance personnel who new something about these projects. The information thus obtained was clear enough to complete this report. After talking with each organization it was decided that traveling to view each project first hand would not be necessary. This information is summarized in Table 1: SFBP Project Status in Utah.

3. PROJECT EVALUATION

Maintenance personnel at each of the six project sites were interviewed to determine if the solar equipment was still installed. If it was installed, was it still operating. If it was installed and operating, were they generally satisfied with its performance. During this interview the characteristics of each system was determined and any strong or weak points were sought. A short summary of each interview follows.

3.1 Indian Health Service Center

The solar collector at this site was a roof mounted array of evacuated glass tubes with a single U-tube heat exchanger inside. Ethylene glycol was circulated between this collector array and a 2700 gallon storage tank. This heated water was intended for domestic use and space heating. The system was designed and installed for $169,220. According to Lyle Smith, the facility manager, the system was installed poorly, not according to specifications, and it never worked correctly. In the summer of 1989 an addition was made to the health center and the solar heating system was removed by the contractor.

Excessive collector failure combined with high replacement cost for the evacuated tubes were the main reason for removing this solar heating system. Air trapped in the upper end of the U-tubes would stop the flow of the heat transfer fluid. This stagnant heat transfer fluid would soon become so hot from the sun that when flow was finally restored the unsupported upper end of these U-tubes would whip and break the evacuated glass tube that surrounded them. Replacement glass tubes were supplied by the original equipment company for $10 each. After they went out of business, replacements were obtained from Solar Tron at $23 each. This system lost as many as 53 tubes in a single week. With this high failure rate, high replacement cost, and excessive down time, the system was finally discarded.

3.2 Zion National Park

Sixteen homes of park rangers had solar DHW systems installed. This consisted of two flat plate roof mounted collectors, pumps to circulate the heat transfer fluid, and a storage tank in the homes to serve as the backup heating system when solar gain was too low to heat the water. According to Jim Starling, from the park maintenance department, these systems have and continue to work well and require no extra maintenance. The installed systems provide the residents with all their hot water needs from May to September, inclusive, and supplement the backup system on winter days when the sun is bright. This project cost $46,256. Two of the installed systems have been removed, not because of any system failure, but rather because the park began to enforce, more rigorously, an ordinance stating that historical houses over 50 years old could not have their external appearance altered. Park personnel were sufficiently pleased with the performance of these solar DHW systems that a total of 30 homes now have similar systems installed on them.

3.3 Federal Building/Courthouse

Maintenance for the Ogden City Federal Building/Courthouse is contracted to Ogden Allied Building Services. Gary Mitchell works for them and is responsible for the physical facilities at this building including the solar DHW system. This solar system consists of eight flat plate collectors (5 ft. by 10 ft. each) with propylene glycol circulated through the collectors to a single tube heat exchanger and four storage tanks. Backup water heating is provided by the building's steam plant. This solar DHW system was designed and installed for $32,500. According to Gary Mitchell the system design was inadequate, its installation was poorly done, and operation and maintenance costs are excessive.

When Gary Mitchell came to work at this site the system was nonoperational. Pumps and check valves were installed incorrectly and the system could not be adequately charged so the collectors were often air bound. These problems have been corrected. Still, even on hot summer days, the building's steam plant is used to make DHW in the mornings because of the low heat transfer area of the single tube heat exchangers and the inadequate amount of thermal storage. Even though this system has shown marginal performance, a similar system has been installed on the Federal Building in Salt Lake City.

3.4 Capitol Reef National Park

Six homes of park rangers had solar DHW systems installed. This consisted of two flat plate roof mounted collectors, pumps to circulate the propylene glycol (the heat transfer fluid), and a storage tank in the homes to serve as the backup heating system when solar gain was too low to heat the water. According to Quinn Willis, from the park maintenance department, the solar collectors have and continue to work well all year long providing the residents with all their hot water needs whenever the sun is bright. This project cost $17,346. Even though the system works, it requires excessive maintenance for two reasons: 1) the heat transfer fluid is not compatible with pump and connector seals which leak and require frequent repairs; and 2) the backup electric heaters in the DHW storage tanks fail as often as twice a year requiring costly replacement. Even though the solar collectors operate well and relieve the residents of monthly water heating bills, the total system is poorly done so that the cost of maintenance and repair—paid for by the government—more than offsets any savings to the residents.

3.5 Natural Bridges National Monument

Four homes of park rangers had solar DHW systems installed. This consisted of two flat plate roof mounted collectors, pumps to circulate the heat transfer fluid, and a storage tank in each home to serve as the backup heating system when solar gain was too low to heat the water. According to Dale Cannon and Joe Miller, from the park maintenance department, these systems worked well until about four years ago when the wrong heat transfer fluid was put into the system resulting in excessive pump and connector leakage. Because of this, all four systems were bypassed and are now nonoperational. These four systems were installed at a cost of $11,564.

3.6 Flamming Gorge Dam

Two separate projects were built at this site. A three panel, roof mounted, flat plate collector system was installed at the visitors' center, at the dam, to augment the installed DHW system. This project cost $6,287. The second project installed solar DHW systems on two government residences in the city of Dutch John at a cost of $6,078. These two systems were similar to those installed at the other parks mentioned above. According to Jed Bryars, from the maintenance department at the dam, the visitors' center system has and continues to work well and seems to be worth while even though no cost savings information has been computed. The second project has been removed. It seems that the responsible government agency treated this project as an experiment and when they were satisfied with it they stopped funding its maintenance. Eventually the systems were taken out of service and finally discarded.

4. CONCLUSIONS

Thirty-one projects at six Utah sites were funded by the Department of Energy during the Solar in Federal Buildings Program. Of these 31 projects, five have been completely removed representing a lost cost of $181,080. Four other projects are still installed but completely nonoperational, adding another $11,564 of lost funds, to make a total of $192,644. Thus, 29% of the SFBP projects constructed in Utah, accounting for 67% of Utah's funding are either no longer installed or nonoperational. Of the remaining 22 projects, seven probably cost more to maintain than they save from gains in solar energy. This represents an additional $49,846 and brings the totals to 16 projects at a cost of $242,490. Again, this represents 52% of the projects and 84% of the funds spent in Utah. Reasons given for these failures by those persons who have worked with these systems include poor design, incorrect installation, lack of training for maintenance personnel, and lack of administrative concern by the sponsoring government agency. Therefore, only 15 projects (48%) at a cost of $46,761 (16%) can be considered successful based on the information obtained by those contacted at the various sites around Utah.

5. RECOMMENDATIONS

It is important for the federal government in general, and the solar industry in particular, to critique itself in projects of this type—to determine where successes and failures occur—to learn from this process so when future projects are needed these errors can be avoided. Without this critical evaluation, of the projects accomplished in Utah, a complete assessment of the Department of Energy's Solar in Federal Buildings Program would not be complete. Based on the information learned from this survey it would be difficult to consider the SFBP projects in Utah a success. These results justify doing similar studies in other states to determine if the unsuccessful Utah projects are unique or they represent the norm for the Solar in Federal Buildings Program.

6. ACKNOWLEDGEMENTS

This project would not have been done without the help of Steve Baer, C.L. Carwile, O.R. Hillig, and the local maintenance personnel at each of the six project site in Utah.

TABLE 1
SFBP PROJECT STATUS IN UTAH

LOCATION	SYSTEM DESIGN	SFBP NO./COST	EQUIPMENT	SYSTEM STATUS	POINT OF CONTACT
Indian Health Service Center Fort Duchesne Utah 84026	Evacuated tube collector for DHW and space heating of the hospital	4039 $169,220	Removed	Removed (never worked correctly)	Lyle Smith Facility Manager (801) 722-5122
Zion National Park Springdale Utah 84767	Sixteen 2-panel DHW systems on 16 park ranger residences	1382 to 1397 $46,256	14 of 16 Installed	All 14 work well	Jim Starling Maintenance Department (801) 772-3256
Federal Bldg/ Courthouse 324 25th St. Ogden Utah 84401	One 8-panel DHW system on a 200,000 sq.ft. public building	1635 $32,500	Installed	Working (high maintenace cost)	Gary Mitchell Ogden Allied Building Services (801) 392-2045
Capitol Reef National Park Torrey Utah 84775	Six 2-panel DHW systems on six park ranger residences	1569 to 1574 $17,346	Installed	Working (high maintenance cost)	Quinn Willis Maintenance Department (801) 425-3791
Natural Bridges Nat'l Monument Monument Valley Utah 84563	Four 2-panel DHW systems on four park ranger residences	1464 to 1467 $11,564	Installed	Not Working (design problems)	Dale Cannon Maintenance Department (801) 259-5174
Flaming Gorge Dam Dutch John Utah 84023	One 3-panel DHW system on the visitors' center at the dam and	1584 $6,287	Installed	Working	Jed Bryers Maintenance Department (801) 885-3234
	Two 2-panel DHW systems on two government employee homes	7001 to 7002 $6,078	Removed	Removed (improper management)	